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Wing Loading, Icing and Associated Aspects of Modern Transport Design

CLARENCE L. JOHNSON

Lockheed Aircraft Corporation

Introduction

The purpose of this paper is to investigate the effect of wing loading on transport airplane design. Wing loading affects the flight characteristics of the airplane in that the higher the unit weight to be carried by each square foot of wing, the higher the speed at which the airplane must fly to sustain that load or the greater must be the angle of attack at which the wing meets the air. Values of wing loading vary from 3 lbs./sq.ft. in gliders and birds to 60 lbs./sq.ft. in racing type aircraft. At the present time, typical transport airplane wing loadings vary from 20 to 35 lbs./sq.ft. of area.

It has been unfortunate that many airplanes in the higher wing loading brackets have had poor flying characteristics for reasons not at all connected with wing loading. The most usual of these faults has concerned stalling characteristics. There is no fundamental reason why an airplane with high wing loading should have worse stall characteristics than those with low wing loading. In fact, due to the higher stalling speed actual control should be improved.

The fact that the stalling speed varies slowly with wing loading is of utmost importance in determining the economic value of the airplane for transport use, as comparatively small changes of wing loading result in a great change of pay load.

For every condition of flight except stalling there is some combination of power and wing loading that will give a constant performance. In a short time, power will be used for the landing and stalling speed conditions to control the airflow around the wing in such a manner that even the minimum speed factor will be a function of power. From this point onward there will be very little cause to consider limitations of wing loading such as are now considered unsafe.

The various steps that are currently being taken to make the use of higher wing loadings safe are:

(a) Improvements in airports and airway facilities will allow higher landing speeds.

(b) The use of improved landing gears which will allow faster landings with better landing control and better braking.

(c) Improvements in engines and propellers are being made available to give better power-weight ratios which improve take-off and emergency safety.

(d) Detailed studies of stability, control factors and wing stalling.

(e) Improved wing flaps are being used and studies made on boundary layer control by the use of engine power.

(f) Studies are being undertaken on icing and related problems toward a solution for keeping airplane efficiency high under all possible conditions.

It is perhaps in the last field that development has been most tardy. This subject will be discussed at quite some length in this paper as it is one of the critical factors affecting wing loading.

Factors Affecting Wing Loading

The problems related to wing loading which now face the aviation industry, come under two broad groups. These are:

Flight Problems

1. Handling characteristics— landing speed, stability, maneuverability
2. Take-off and climb performance
3. Icing effects
4. Pilot technique

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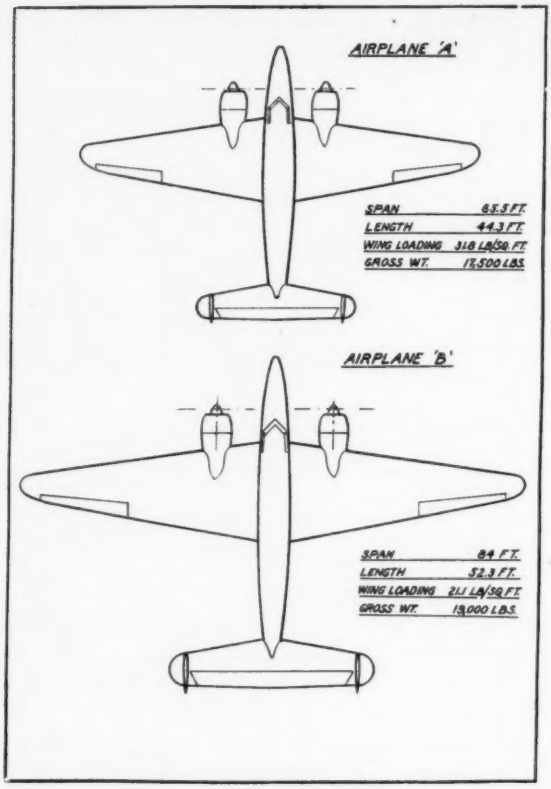

FIG. 1. Comparative planform drawings of airplanes "A" and "B."

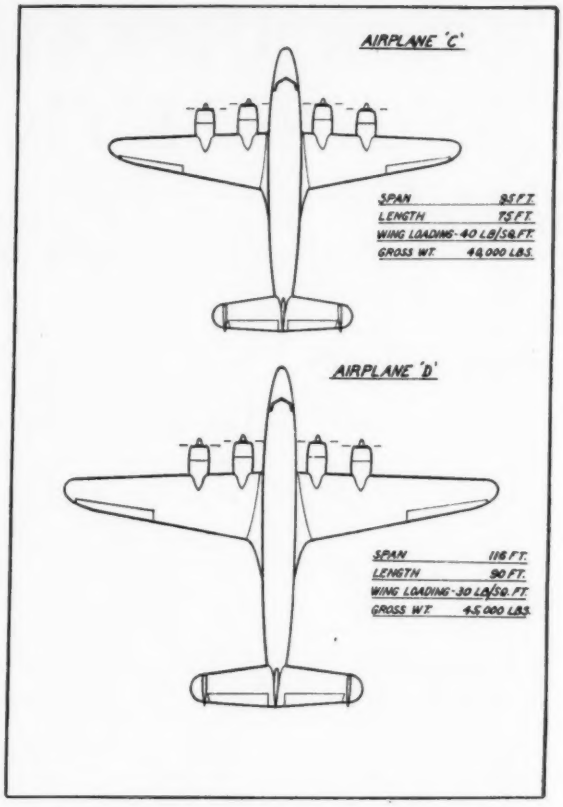

FIG. 2. Comparative planform drawings of four-engined airplanes "C" and "D."

ECONOMIC PROBLEMS

1. Payload carried
2. Performance gained
3. Airplane initial cost
4. Operating costs for given speed
5. Hangar size, servicing problems
6. Crew required

The preceding items will be discussed and enlarged upon. The best way to make various points clear is by use of examples which cover the present design trend for the coming series of transport airplanes and also cover the type of equipment now being used. The problem will be attacked in the following manner:

1. Two bi-motor airplanes will be designed to study current transport types. The first has a wing loading of 31.8 lbs./sq.ft. and a gross weight of 17,500 lbs. This airplane, designated as "Airplane A," has already been flying for quite some time so its performance and weight characteristics are known exactly. For the low wing loading class, a second bi-motor, "Airplane B," is designed, with a wing loading of 21.1 lbs./sq.ft. Both airplanes, to be comparable, must fulfill the following conditions:

(a) The airplanes must carry identical payloads the same distance when equipped with a given power plant. For the example considered, the payload is 3775 lbs., the distance 950 air miles and the engines Pratt & Whitney Hornets.

(b) Both airplanes meet C.A.B. requirements structurally.

(c) Both airplanes have the same stability. The airplane with the larger wing must have a correspondingly large vertical and horizontal tail. The fuselage length must also be greater, but due to the smaller relative c.g. travel on the lightly loaded airplane, the fuselage length does not vary directly with the wing span.

(d) The wing airfoil section and aspect ratio must be the same for both airplanes.

(e) The fuselage cross-sectional area is a constant.

(f) Crew and passenger facilities are the same for both airplanes.

(g) Both airplanes have the same type of high lift wing flap and landing gear.

2. To study projected transport designs, two four-engined airplanes will also be considered. Four-engine airplane "C" has a take-off wing loading of 40 lbs./sq.ft. Airplane "D" is designed to have a 30 lbs./sq.ft. wing loading. Both four-engine airplanes have Wright G205A two speed supercharger engines, and are intended to carry approximately 8500 lbs. of payload 1100 air miles at 250 m.p.h. cruising speed. The crew consists of 5 persons. Tricycle type landing gears are

used and the Lockheed-Fowler flap as a high lift device. The four-engine aircraft are designed on a comparative basis to meet the requirements of Item (1 b–g) above.

Figs. 1 and 2 show the comparative sizes of all four airplanes discussed, while Table 1 summarizes various physical and performance characteristics.

It is of utmost importance to make careful weight analysis for all airplanes involved in order to keep the comparison valid. The airplanes with light wing loadings have naturally higher wing and tail weights than those of higher wing loading, although the weight per sq.ft. of area is considerably less. To evaluate landing gear weight, care must be taken to use tire and wheel sizes currently available. In some cases, this will penalize one aircraft more than its competitor.

For a given cruising speed, the airplane with the light wing loading requires more engine power and therefore more fuel than one with a higher wing loading.

This subtracts from the net useful load. Table 2 gives a complete study of various factors involved for two different operating problems of the four-engine airplanes.

The ranges taken for a comparative study are actual air miles flown against zero wind with no reserve fuel provided. Actual operating air-line range would therefore be about 50 per cent of the distances indicated in all cases.

Considering the above, it will be seen that the two-engine airplane with light wing loading is 1500 lbs. heavier than the one with the high wing loading while the corresponding figure for the four-engine airplanes is 5000 lbs. A study of various similar airplanes will convince anyone interested in the accuracy of the preceding weight study.

It is well to note the comparative dimensions of the airplanes involved from a point of view of hangar space required and also the selling prices. Current two-engine transports sell for approximately $7.30 per pound of empty weight, while the less numerous four-engine airplanes are available for about $10.00 per pound.

Due to the development of low drag, high lift wing flaps, the problem of maneuverability at slow speeds and the actual landing speed problem has been kept well in hand. Most of the present types of transport airplanes are equipped with split type wing flaps which are not of great benefit in improving maneuverability at approach speed conditions. Transport airplanes now being designed will make definite use of flaps for maneuvering, so that it is in order to give an example of equivalent wing loadings for equal maneuverability. Consider Fig. 3, which shows the lift obtainable at various angles of attack for an airplane with flaps retracted and a 27.8 lbs./sq.ft. wing loading, compared to the same curve for an airplane with modern flaps set for approach maneuvering condition. When flying at 120 m.p.h., the unflapped airplane has an angle of attack of slightly over 5° and it has reserve lift to make a 2G pull-

TABLE 1

Physical Characteristics of Four Airplanes Studied

* Two speed superchargers.

† Tail area ratios shown, expressed in terms of the basic tail areas of Airplanes "A" and "C," are required to keep stability factors constant.

ITEM	TWO ENGINE AIRPLANE		FOUR ENGINE AIRPLANE	
Airplane	A	B	C	D
No. of Engines	2	2	4	4
Engine Type	P & W Hornets	P & W Hornets	W.A.C. 205A *	W.A.C. 205A *
Rated BHP and Alt.	800 at 5000 ft.	800 at 5000 ft.	1000 at 4500 ft. and 900 at 14,000 ft.	1000 at 4500 ft. and 900 at 14,000 ft.
Gross weight—Lbs.	17,500	19,000	40,000	45,000
Wing Area—Sq. ft.	551	900	1,000	1,500
Wing Loading—Lbs./sq. ft.	31.8	21.1	40.0	30.0
Power Loading—Lbs./BHP	10.94	11.90	10.0	11.26
Empty Weight—Lbs.	11,000	12,340	25,330	29,100
Useful load—Lbs.	6,500	6,660	14,670	15,900
Payload—Lbs.	3,775	3,775	8,597	8,504
Range with above payload	950	950	1,100	1,100
Speed for above range—MPH	215	198	250	250
Wing span—ft.	65.5	83.7	95	116.2
Wing area ratios	100%	163%	100%	150%
†Horizontal tail area ratio	100%	163%	100%	150%
†Vertical tail area ratio	100%	163%	100%	150%
Aspect ratio	7.78	7.78	9.03	9.03
Type landing gear	Normal	Normal	Tricycle	Tricycle
Overall length				
Change in wing weight—Lbs.	—	800	—	1,860
Change in tail weight—Lbs.	—	205	—	540
Change in fuselage wt.—Lbs.	—	230	—	850
Change in gear weight—Lbs.	—	85	—	270
Change in Misc. weight—Lbs.	—	20	—	250
Change in empty weight—Lbs.	—	1,340	—	3,770
Approximate airplane cost	$80,000	$89,700	$253,000	$291,000

TABLE 2

Comparison of Range and Payload Data on Four-Engined Airplanes "C" and "D"

Wing Loading *vs.* Payload:

		Airplane "C"	Airplane "D"
Gross Weight		40,000 lbs.	45,000 lbs.
Empty Weight		25,300	29,100
Useful Load		14,670	15,900
CREW WEIGHTS			
2 pilots		340 lbs.	340 lbs.
Radio operator		170	170
Steward		150	150
Stewardess		130	130
RANGE DATA			
Case A	Cruising Speed—MPH	250	250
	Cruising Altitude—Ft.	12,000	12,000
	Power required per engine—BHP	650	790
	Fuel consumption—specific *	.435	.45
	Fuel used per hour—gallons	189	237
	Miles per gallon of fuel	1.32	1.055
	Fuel required for 1100 miles—Gal.	833	1,041
	Oil carried for 1100 miles—Gal.	38	48
	Weight of fuel & oil for 1100 miles	5,283	6,606
Case B	Cruising Speed—MPH	200	200
	Cruising Altitude—Ft.	8,000	8,000
	Power required per engine—BHP	455	520
	Fuel consumption—specific	.42	.425
	Fuel used per hour—gallons	127.5	147.5
	Miles per gallon of fuel	1.57	1.35
	Fuel required for 1100 miles—Gal.	700	815
	Oil carried for 1100 miles—Gal.	32	37
	Weight of fuel & oil for 1100 miles	4,440	5,168
Payload for 1100 miles range at 250 MPH at 12,000 ft.—lbs.		8,597	8,504
Payload for 1100 miles range at 200 MPH at 8,000 ft—lbs.		9,440	9,942
Payload for 1900 miles range at 200 MPH at 8,000 ft—lbs.		6,200	6,163

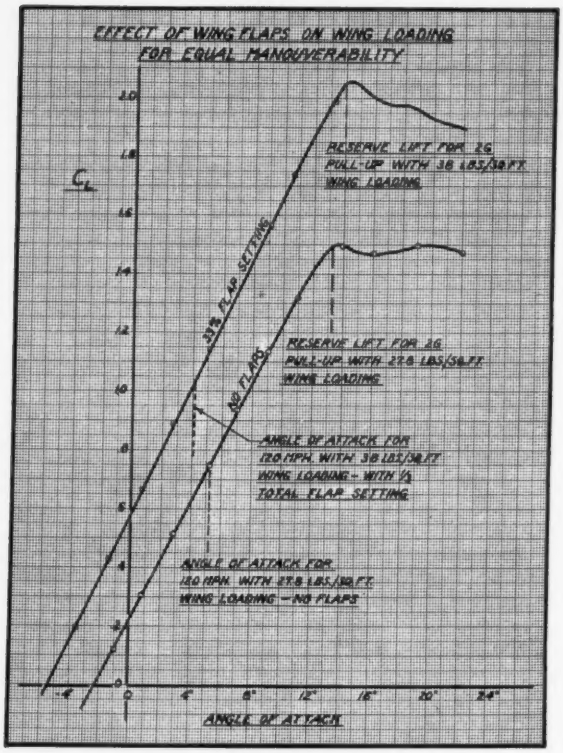
EFFECT OF WING FLAPS ON WING LOADING FOR EQUAL MANOUVERABILITY
C_L
RESERVE LIFT FOR 2G PULL-UP WITH 38 LBS/SQ.FT. WING LOADING
1/3 FLAP SETTING
NO FLAPS
RESERVE LIFT FOR 2G PULL-UP WITH 27.8 LBS/SQ.FT. WING LOADING
ANGLE OF ATTACK FOR 120 MPH. WITH 38 LBS/SQ.FT. WING LOADING - WITH 1/3 TOTAL FLAP SETTING
ANGLE OF ATTACK FOR 120 MPH. WITH 27.8 LBS/SQ.FT. WING LOADING - NO FLAPS
ANGLE OF ATTACK

FIG. 3.

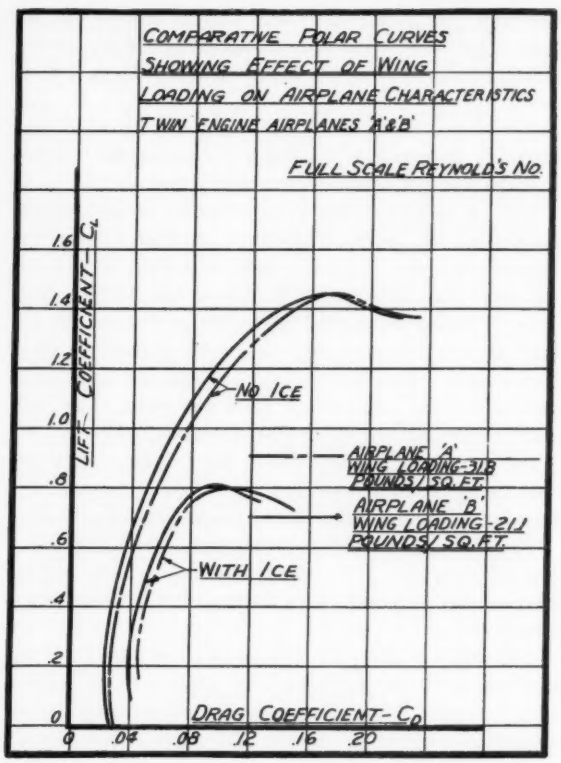
COMPARATIVE POLAR CURVES SHOWING EFFECT OF WING LOADING ON AIRPLANE CHARACTERISTICS TWIN ENGINE AIRPLANES 'A' & 'B'
FULL SCALE REYNOLD'S NO.
LIFT COEFFICIENT - C_L
NO ICE
AIRPLANE 'A' WING LOADING - 31.8 POUNDS/SQ.FT.
AIRPLANE 'B' WING LOADING - 21.1 POUNDS/SQ.FT.
WITH ICE
DRAG COEFFICIENT - C_D

FIG. 4.

up without stalling, for the wing loading of 27.8 lbs./sq.ft. The flapped airplane flying with one-third flap extension at 120 m.p.h. is carrying 38 lbs./sq.ft. of wing area and has exactly the same maneuverability in that it can make a 2G pull-up without stalling also. A 2G pull-up is equivalent to a 60° bank. This example shows the value of the proper flap type for maneuvering. The values of wing loading shown correspond roughly to the landing values for the four-engined airplanes having 40 and 30 lbs./sq.ft. take-off wing loading, respectively. There is often considerable comment that when the flaps are extended, the airplane will have a very low rate of climb but this is not true for the example shown. With one engine inoperative, the four-engined airplane with the 38 lbs./sq.ft. wing loading will have a rate of climb of over 600 feet per minute at normal (not take-off) power.

The conclusion can be drawn that as far as handling characteristics and stability are concerned, higher wing loadings offer no serious problems. It might also be said that present maneuvering speeds can still be maintained on a well designed airplane by proper use of wing flaps although the limiting landing speed will increase slightly over values now in use. The latter factor is not considered serious when good stall characteristics are available, as they certainly must be, and when ample power is used to give good climb in emergency. The problem dealing in the effect of wing loading on rudder controllability will not be discussed here, but has been thoroughly studied.* The conclusions resulting from the study of the rudder controllability problems do not show that any great difficulties will be encountered in obtaining rudder control after engine failure.

TAKE-OFF AND CLIMB PERFORMANCE

In order to evaluate an effect of wing loading on performance and climb it is necessary to make a complete performance analysis of the four airplanes referred to above. Without discussing the details, the basic airplane characteristics are presented on the following two curves. The data shown applies to the full scale airplanes and it is based on a large number of wind-tunnel and flight tests. While the airplanes with the lower wing loading have lower drag coefficients than those with higher loading, their total drag is considerably greater than the drag of the latter airplanes for almost every flight condition. The curves labeled "with ice formation" will be discussed later. (See Figs. 4 and 5.)

A comparative performance of four airplanes is summarized in Figs. 6, 7, 8 and 9, as well as in tabular form as shown on page 53 (Table 3).

The outstanding advantage of the heavily loaded airplanes in speed and climb at normal altitudes is very

* *Rudder Control Problems on Four-Engine Airplanes*, C. L. Johnson, S.A.E. Journal, June, 1940.

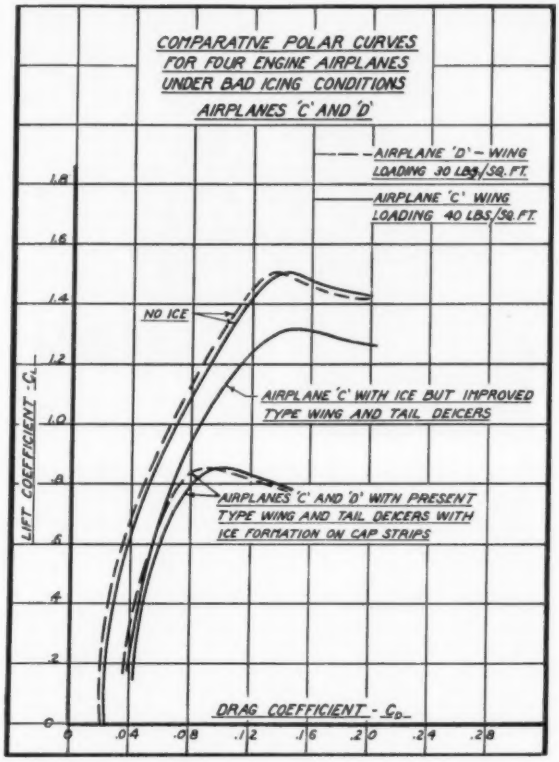
COMPARATIVE POLAR CURVES
FOR FOUR ENGINE AIRPLANES
UNDER BAD ICING CONDITIONS
AIRPLANES 'C' AND 'D'
AIRPLANE 'D' - WING LOADING 30 LBS/SQ. FT.
AIRPLANE 'C' WING LOADING 40 LBS/SQ. FT.
NO ICE
AIRPLANE 'C' WITH ICE BUT IMPROVED TYPE WING AND TAIL DEICERS
AIRPLANES 'C' AND 'D' WITH PRESENT TYPE WING AND TAIL DEICERS WITH ICE FORMATION ON CAP STRIPS
LIFT COEFFICIENT - C_L
DRAG COEFFICIENT - C_D

FIG. 5.

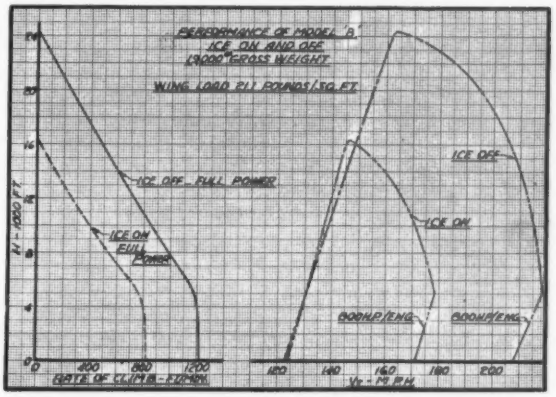

FIG. 7.

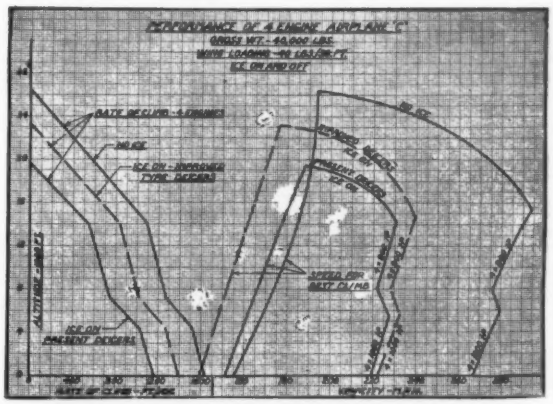
PERFORMANCE OF 4 ENGINE AIRPLANE 'C'
GROSS WT. - 40,000 LBS.
WING LOADING - 40 LBS./SQ. FT.
ICE ON AND OFF
RATE OF CLIMB - 4 ENGINES
NO ICE
ICE ON - IMPROVED TYPE DEICERS
ICE ON - PRESENT DEICERS
SPEED FOR BEST CLIMB
ALTITUDE - FEET

FIG. 8.

strikingly shown. In both cases the smaller airplanes with higher wing loadings are approximately 26 m.p.h. faster than their comparable designs with lighter wing loading. There is a slight difference in absolute ceiling in favor of latter designs, but the low altitude climb is better for the higher wing loading. The great difference in speed for a given power is an important factor in the economic operation of the airplane, particularly when it is considered that less fuel need be carried to go a given distance, and therefore the payload can be increased. Airplane D, at a cruising speed of 250 m.p.h., will use 22 per cent more engine power and a correspondingly greater amount of fuel than that used by Airplane C. The fuel cost alone for Airplane D will run over three cents per mile more than that of Airplane C. When all factors are considered, including first cost and the effect of size on maintenance, the probable added operating cost per mile would give a differential of

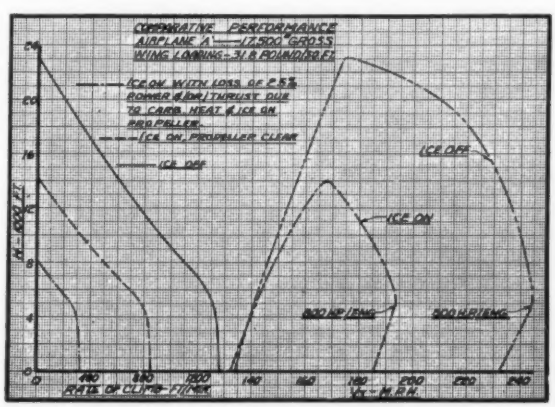
COMPARATIVE PERFORMANCE
AIRPLANE 'A' — 12,500 GROSS
WING LOADING - 31.8 POUNDS/SQ. FT.
ICE ON WITH LOSS OF 2.5% POWER & THRUST DUE TO CARB. HEAT & ICE ON PROPELLER
ICE ON, PROPELLER CLEAR
ICE OFF
ICE OFF
ICE ON
600 HP/ENG.
800 HP/ENG.
RATE OF CLIMB - F.P.M.

FIG. 6.

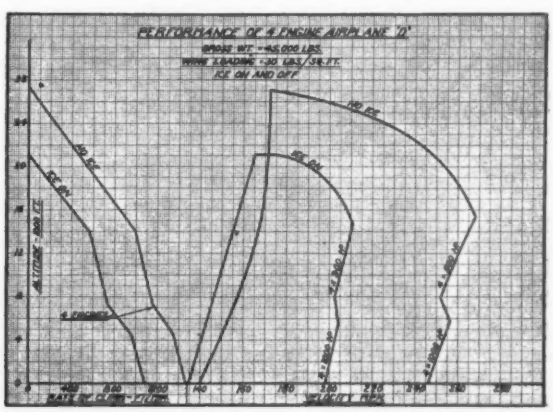

FIG. 9.

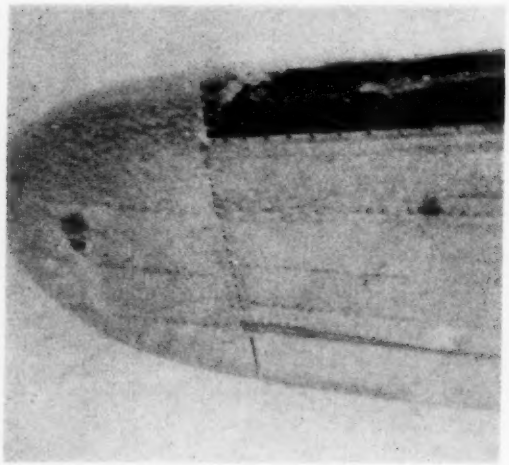

FIG. 10. Ice formation on Electra 10-A airplane. Note ice formation on top deicer attaching strips and rivets.

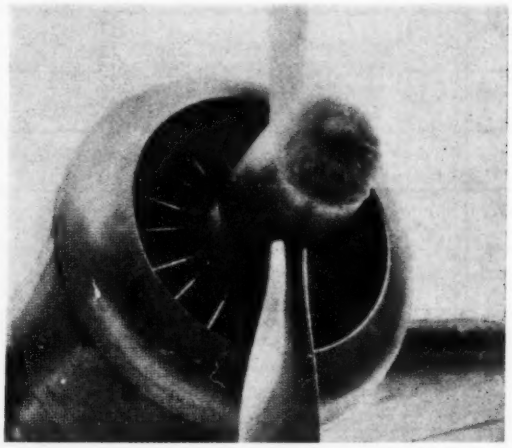

FIG. 12. Ice formation on propeller spinner. Cowl ice has fallen off.

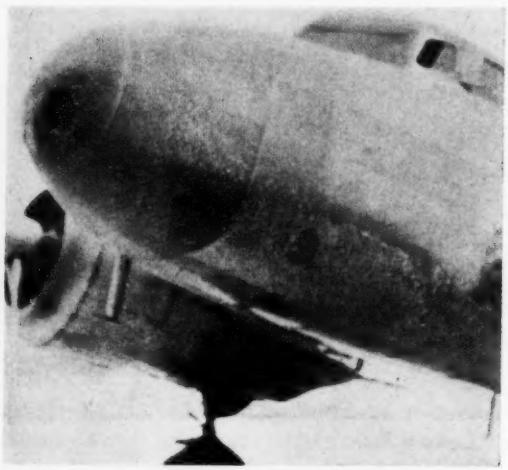

FIG. 11. Fuselage and pitot tube icing—Lockheed Electra.

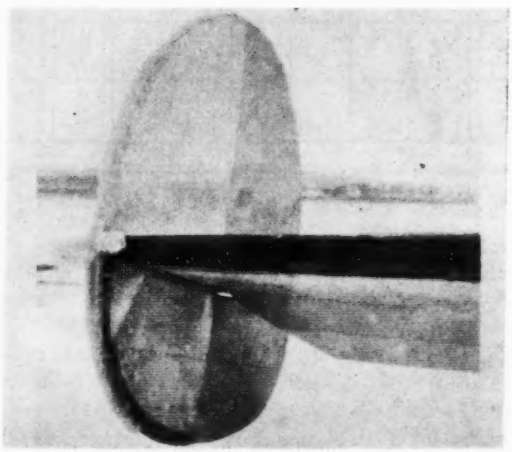

FIG. 13. Tail surface icing.

five cents. The engines for the lightly loaded airplanes must run continually at higher power outputs than that required for the higher wing loaded airplanes, so engine maintenance and reliability is actually affected directly. This gives an added safety margin to the airplanes with the heavier wing loading and to this factor must be added, also, greater range, speed and climb. These additional safety margins go a long way to compensate for a slight increase in landing speed.

The problem of take-off with heavy wing loadings may be solved by the use of higher power and take-off flaps. For the airplanes considered, the present C.A.B. take-off requirements will be met in all cases.

AIRPLANE ICING

The icing problem is one of the most important ones facing the aviation industry today. There are a large number of types of ice and conditions under which it forms; a hard glaze ice has been reported as forming on an airplane at temperatures as low as $-40°$F. Under this condition the ice was so smooth that no detrimental effect could be noticed in the airplane performance. Perhaps the most general type of ice which forms on aircraft is a fairly soft rime ice which is very rough and which can form in large amounts very quickly. There are little actual data available on the weight of ice that airplanes have picked up, but in extreme cases it is estimated that this weight might be as much as 6 per cent of the gross weight of the airplane.

The relation between wing loading and icing has not been carefully studied to date and the opinion exists among many pilots that an airplane with a higher wing loading would be affected more detrimentally by ice than one with light wing loading. This is not an actual fact. The airplane with the larger wing area

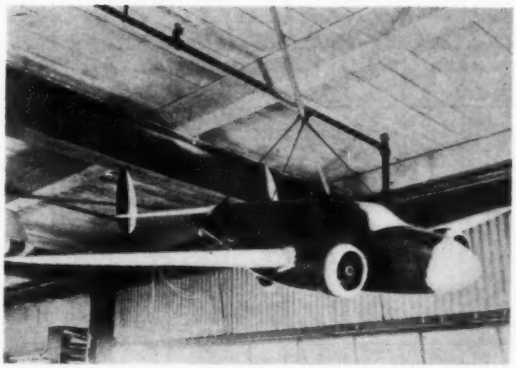

FIG. 14. Wind-tunnel model prepared for simulating icing tests.

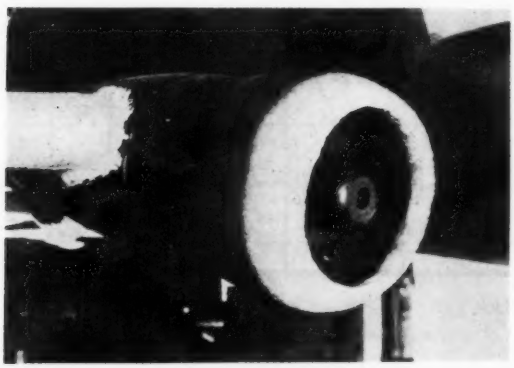

FIG. 15. Simulated cowl icing.

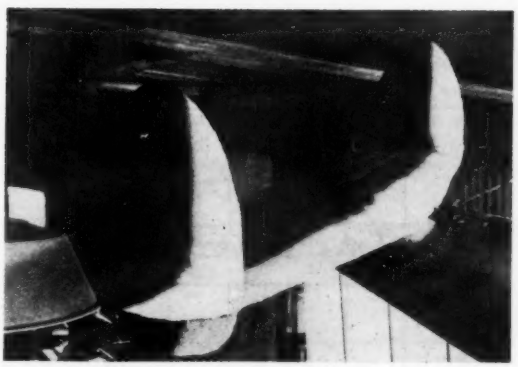

FIG. 16. Tail on wind-tunnel model showing preparation for icing tests.

picks up more ice due to the larger area exposed. Furthermore it remains in the icing conditions a longer period of time. In order to evaluate this problem, the Lockheed Aircraft Corporation has in the past two years been making a large number of wind-tunnel tests on the effect of ice on airplane performance. The results of these tests were checked in flight on a northern airline. Figs. 10, 11, 12 and 13 are pictures of a Lockheed Electra airplane which was iced to the extent that

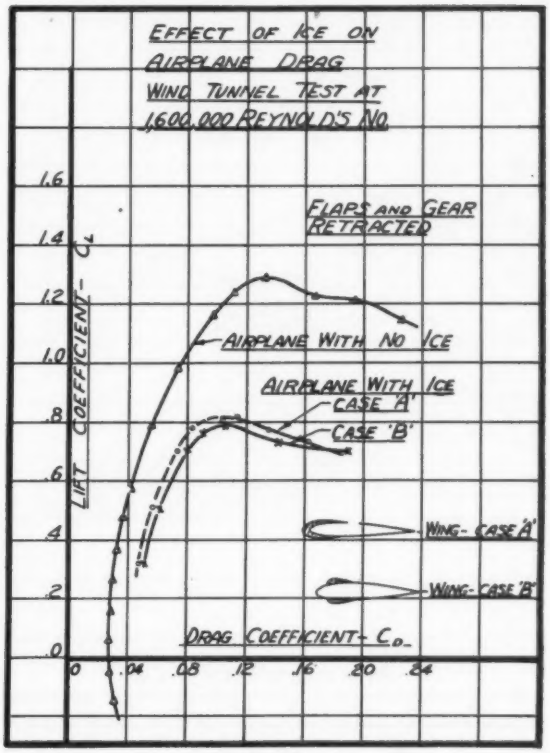

FIG. 17.

the indicated high speed with all the power available to the pilot with carburetor heat applied, was only 90 m.p.h. at 5000 feet. Practically full power was required for landing and only the pilot's skill prevented serious consequences in this particular case. The pictures were taken after the airplane had been standing in a heated hangar for one hour in which time all of the cowling ice fell off the ship. Every rivet on the outboard wing panel is accentuated by ice. As a result of this and other experiences, a series of wind-tunnel tests were undertaken to determine the possibility of representing ice effectively on a wind-tunnel model. It was found possible to obtain a very good representation by applying a mixture of plaster of paris and airplane dope to the various parts of the airplane as shown in the following figures.

Complete tunnel tests were made and the effect of ice on the different parts of the airplane evaluated carefully. Changes of lift, drag and stability were measured under widely varying conditions. The ice conditions represented by the curve data included in this report represent a very severe icing condition of a type not adequately removed by the present type of wing deicer. In certain cases, ice has built up on the deicer cap strips to such an extent no benefit has been derived from the operation of the deicing boot. Fig. 17 shows the results of ice formation on the complete airplane as indicated by the photographs in Figs. 14, 15 and 16. The most important result due to the presence

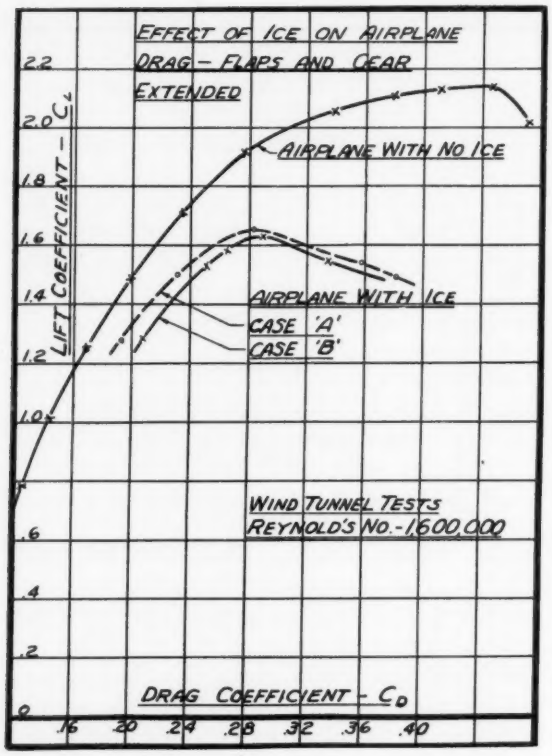
EFFECT OF ICE ON AIRPLANE DRAG - FLAPS AND GEAR EXTENDED
LIFT COEFFICIENT - C_L
AIRPLANE WITH NO ICE
AIRPLANE WITH ICE
CASE 'A'
CASE 'B'
WIND TUNNEL TESTS
REYNOLD'S NO. - 1,600,000
DRAG COEFFICIENT - C_D

FIG. 18.

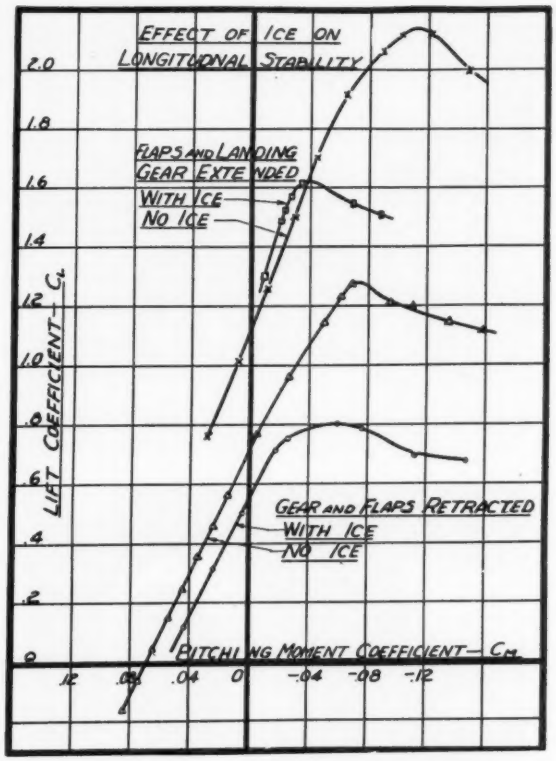

FIG. 20.

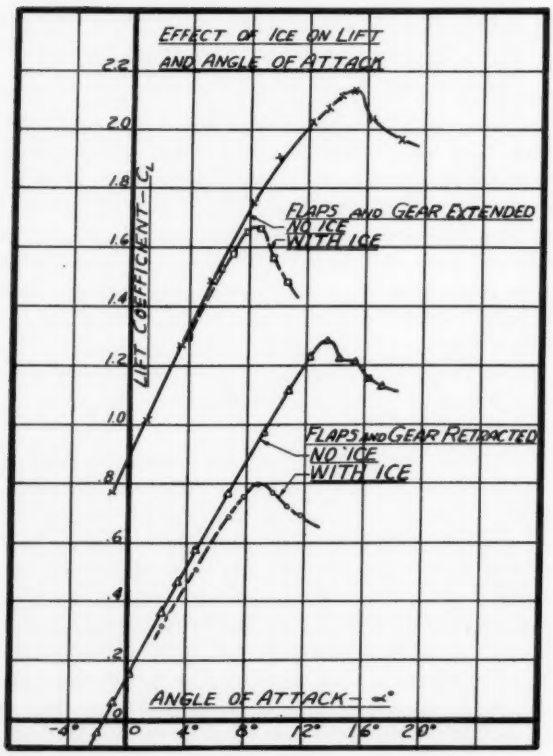

FIG. 19.

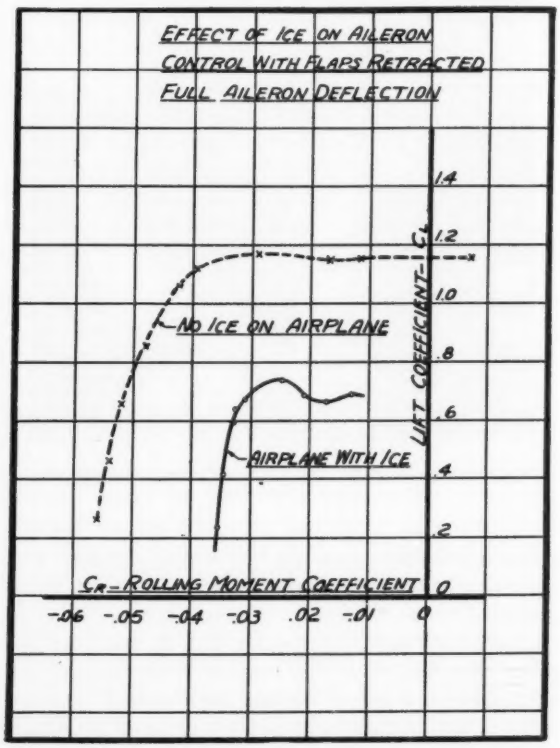
EFFECT OF ICE ON AILERON CONTROL WITH FLAPS RETRACTED
FULL AILERON DEFLECTION
NO ICE ON AIRPLANE
AIRPLANE WITH ICE
LIFT COEFFICIENT - C_L
C_R - ROLLING MOMENT COEFFICIENT

FIG. 21.

of rime ice is a very substantial reduction in the maximum lift available. This reduction amounted to 32 per cent for the case with the flaps retracted and 23 per cent with the wing flaps extended. At the same time the airplane drag increased 47 per cent in the cruising condition. (See Fig. 18.) In a test with the ice removed over the deicer, but with a $1^1/_2$ in. ridge of ice on the cap strips of the deicing boot (dimensions shown for full scale), the lift was reduced and drag increased more than for the condition where the leading edge was iced completely. One of the most serious effects of icing was the great reduction in angle of attack for maximum lift when ice was present. (See Fig. 19.) Because of the fact that the normal stalling angle is reduced from 13° to 9° the pilot is confused because he has no means for knowing when he is approaching the stall. If the airplane without ice would give a stall warning due to tail buffeting at a speed of 5 m.p.h. before the stall, under icing conditions this would not be obtained, because the airplane stalls at a much lower angle of attack. Only an effective angle of attack indicator can solve this problem unless the ice removal is complete. It will be noted in the following figures that in spite of the decrease of lift, both with flaps extended and retracted, the airplane characteristics remain normal and flaps should be used for landing. A test was run to determine whether icing of the gap between the wing and the flap would have any serious effect on the aerodynamic characteristics. Outside of a reduction in maximum lift of approximately 10 per cent there is nothing to fear from this problem.

The effect of ice on longitudinal stability is normally small (see Fig. 20), in fact for the condition tested there was practically no change of stability. It should be pointed out, however, that the longitudinal stability will be affected if the icing conditions for wing and tail are not fairly similar. For instance, if the wing was heated to remove all ice and no provision was made for the tail, there might be an adverse effect on stability and control.

The presence of ice on the wing leading edge ahead of aileron reduces the aileron control substantially as shown in Fig. 21. The amount of rolling moment available with full aileron deflection is reduced to 64 per cent of its normal value for the ice conditions simulated.

It was interesting to note that the stall characteristics of the airplane tested improved when ice was on the wing. This effect has since been noted also by pilots flying the airplane in question. When fixed leading edge slots are used, ice will form on the lower lip of the slot and in some cases close the slot completely. (See Fig. 22.)

This effect is easily counteracted by a small deicer shoe installed on the slot lip. When the preceding tests had been completed, flight measurements carried out in conjunction with a northern airline gave almost exact agreement with the results obtained from the wind-tunnel test. Several photographs are shown which

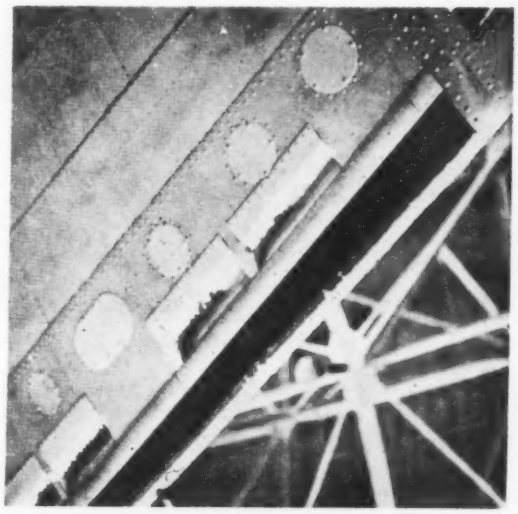

FIG. 22. Icing of fixed slots with no deicer boots.

indicate the type of ice which can be accumulated on an airplane. The ice accumulation between the nacelle and fuselage shown in Fig. 23 was obtained in five minutes under heavy icing conditions. This is a good example of insufficient deicer coverage. The other figures show the effect of rivets in adding to the general roughness. (See Figs. 24 and 25.) Inasmuch as the new transport airplanes will be very smooth, this effect will not be present. Fig. 26 shows the effect of ice formation or of any spanwise protuberance on the maximum lift of an airfoil. Two effects are shown on the curves. One is the fact the higher the protuberance the greater the disturbance and the other is the important effect of the chordwise location of the element. It will be seen that for a one-half in. high ice formation located at the 5 per cent chord point on a wing with a chord of 100 in., the maximum lift of the airfoil is only 54 per cent of the lift of the basic wing. If the protuberance is moved back to the 15 per cent chord point the maximum lift is 86 per cent of that of the basic wing. Most of our present day deicers extend only to the 5 per cent chord point on the wing. (See Fig. 27.) Therefore, when any substantial ice deposit builds up behind the

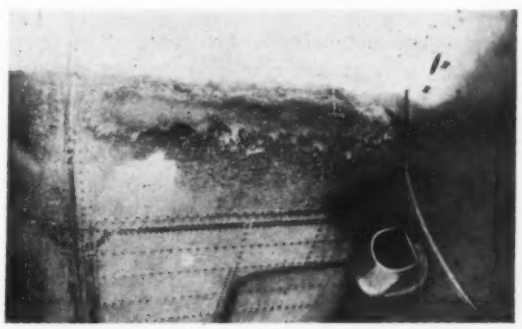

FIG. 23. Four inches of ice accumulated in five minutes under heavy icing conditions.

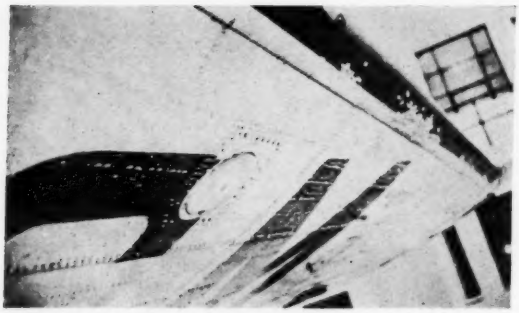

FIG. 24. Wing ice accumulation.

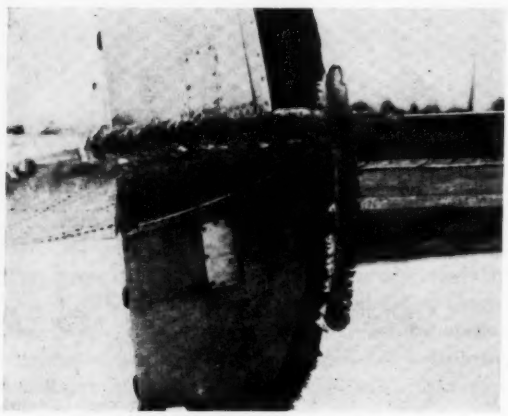

FIG. 25. Tail ice accumulation, showing curious formation obtained. Note insufficient deicer coverage.

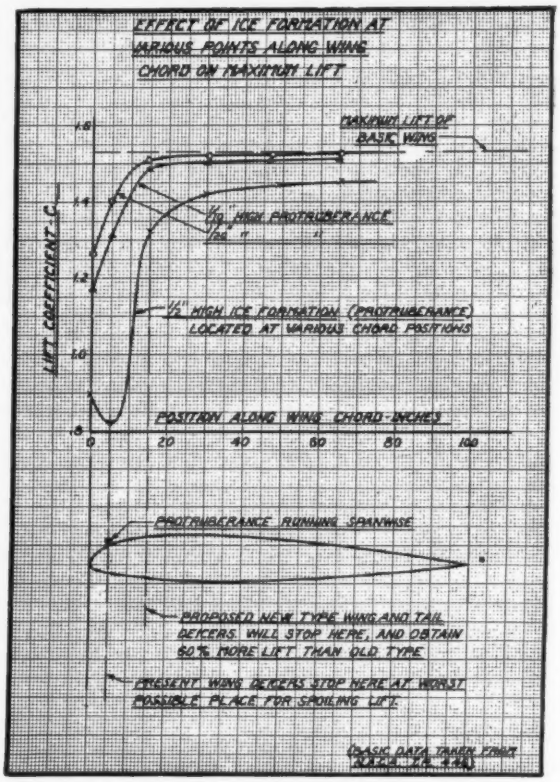
EFFECT OF ICE FORMATION AT VARIOUS POINTS ALONG WING CHORD ON MAXIMUM LIFT
MAXIMUM LIFT OF BASIC WING
LIFT COEFFICIENT C_L
1/8" HIGH PROTRUBERANCE
1/4" HIGH ICE FORMATION (PROTRUBERANCE) LOCATED AT VARIOUS CHORD POSITIONS
POSITION ALONG WING CHORD-INCHES
0
20
40
60
80
100
PROTRUBERANCE RUNNING SPANWISE
PROPOSED NEW TYPE WING AND TAIL DEICERS WILL STOP HERE, AND OBTAIN 50% MORE LIFT THAN OLD TYPE
PRESENT WING DEICERS STOP HERE AT WORST POSSIBLE PLACE FOR SPOILING LIFT

FIG. 26.

deicer or on the cap strip which holds it in place, we immediately obtain the maximum spoiling effect which it is possible to obtain. This is one of the main reasons for the poor performance of present aircraft under icing conditions. Two other factors having the same effect are insufficient deicer coverage and clinging of the ice to the deicer boot itself. Several steps have been taken to eliminate the last two mentioned factors and at the present time the Lockheed Aircraft Corporation is cooperating with the deicer boot manufacturers in making wind-tunnel tests on an improved deicer which will extend back three times as far on the top surface of the wing as our present deicers and twice as far on the bottom.

Icing affects not only the lift and drag of the airplane, but also engine operation due to carburetor icing and a number of various airplane accessories. Figs. 28 and 29 show icing wind-tunnel tests, made to determine the effect of the presence of guide vanes in an air scoop for supplying air to an engine or for ventilation purposes. It will be noted that when the vanes were installed in the scoop, complete closure resulted in a short time.

ICING AND WING LOADING

Using as a basis the information derived in the wind-tunnel tests indicated above, the performance of Air-

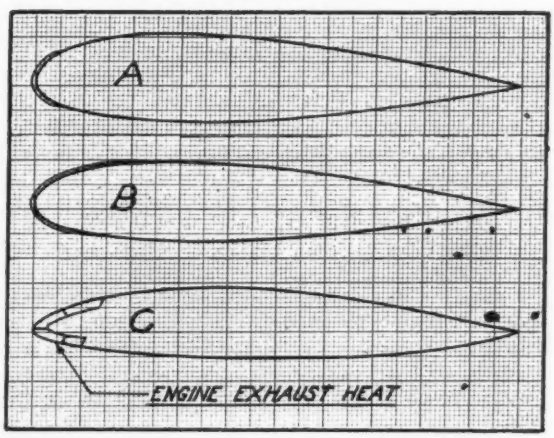

FIG. 27. Developments in wing deicing methods. (a) Present deicing boot (wings not generally flush riveted). (b) Improved deicing boot (for next series of transport aircraft—wings very smooth).

Much study now being given to use of engine exhaust heat for deicing. Definitely promising when mechanical problems are solved.

planes A, B, C and D has been evaluated. The icing condition assumed has been very severe as shown in Figs. 14 and 16 and this is particularly true for the four-engined airplanes. The larger the airplane, the less the relative effect of picking up a given amount of ice. This factor has not been included in the computations

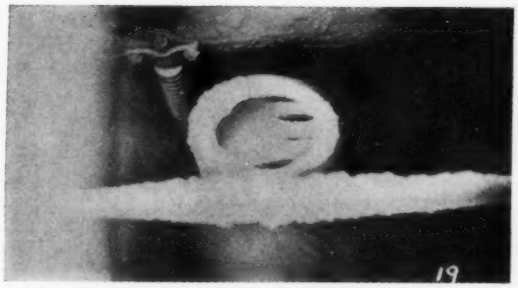

FIG. 28. Air scoop with guide vanes tested in Goodrich icing tunnel. Note complete closure.

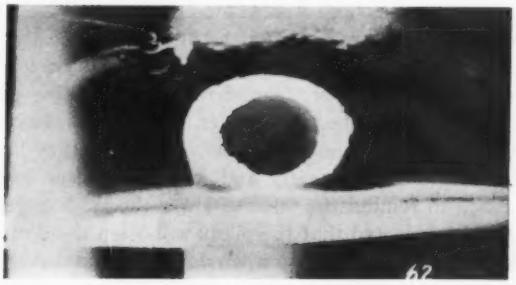

FIG. 29. Same scoop as Fig. 29 without guide vanes. Scoop remains open.

shown as it is counteracted by neglecting the weight of the ice picked up. Performance curves for all airplanes are shown with and without ice and also for Airplane C equipped with improved deicers and under icing conditions. It is not expected that the new type deicer will greatly decrease the drag at high speed, but considerable improvement in rate of climb and ceiling results from its use. Tables 3, 4 and 5 show the comparison between the various airplanes under similar ice conditions as well as for the case with no ice. The airplane with heavier wing loadings exhibit the same performance advantage with ice that they do without ice, although the increments of speed and climb are not so great. While the heavily loaded airplanes do not have as high three- or four-engined ceilings as the lightly loaded ones, they have better climb at normal altitudes. The stalling speeds are affected more than any other performance item and it is primarily in connection with this factor that the new type of deicer will be beneficial, although the three-engined ceiling for the airplane with 40 lbs./sq.ft. wing loading will be increased by 34 per cent.

Higher wing loadings are fully justified on the basis of the evidence shown below.

PILOT TECHNIQUE

The use of wing flaps for maneuvering will require very little change in the piloting technique now being

TABLE 3

Performance Comparison Four-Engined Airplanes "C" and "D"

Wing Loading—Airplane "C"—40 lbs./sq.ft.

Wing Loading—Airplane "D"—30 lbs./sq. ft.

* It should be realized that the condition of icing discussed in this paper is extremely severe and seldom encountered. Many types of ice are encountered which are completely or satisfactorily removed by rudder deicing boots.

† Present small-coverage deicing boots.

ITEM	ICE ON * †		ICE OFF	
	Airplane C	Airplane D	Airplane C	Airplane D
HIGH SPEED at critical altitude—MPH	230	211	294	268
RATE OF CLIMB sea level—ft./min.	1160	1080	1640	1460
ABSOLUTE CEILING 4 engines	19,600	20,500	26,400	27,200
ABSOLUTE CEILING 3 engines	13,000	14,600	20,700	21,600
STALLING SPEED flaps up	135	117.5	102	88.5
RATE OF CLIMB on 3 engines at sea level —ft./min.	520	490	940	840
STALLING SPEED flaps down	89.7	77.6	79.0	68.3
SPEED FOR BEST RATE OF CLIMB	150	135	155	140
POWER REQUIRED for 250 mph at 12,000 ft. altitude—BHP	—	—	4 x 650	4 x 790
POWER REQUIRED for 200 MPH at 8,000 ft. altitude—BHP	4 x 710	4 x 870	4 x 455	4 x 520

TABLE 4

Performance Comparison, Twin-Engined Airplanes "A" and "B"

ITEM	ICE ON		ICE OFF	
	Airplane A	Airplane B	Airplane A	Airplane B
HIGH SPEED—5000 ft	194	178	245	218
RATE OF CLIMB sea level—ft./min	850	820	1360	1210
ABSOLUTE CEILING two engines—ft	14,200	16,300	23,000	24,400
STALLING SPEED flaps up—MPH	110	90	90.3	74
STALLING SPEED flaps down—MPH	81	66	70	57
SPEED FOR BEST RATE OF CLIMB—MPH	133	124	135	124
SINGLE ENGINE CEILING feet	None	None	9600	10,100
REDUCTION IN RANGE DUE TO ICE	23%	20%	—	—
CRUISING SPEED 65% power—10,000 ft.—MPH	166	159	215	198
RANGE with 350 gal. fuel at 65% power—miles	733	702	950	875

TABLE 5

Estimated Effect of Improved Type Rubber Deicers on Airplane Performance

Airplane "C"—Wing Loading, 40 lbs./sq.ft.

ITEM	ICE ON	
	Present Deicer	Improved Deicer
HIGH SPEED at critical altitude	230 MPH	239 MPH
RATE OF CLIMB—sea level	1160 ft./min.	1270
ABSOLUTE CEILING—3 engines	13,000 ft.	17,400 ft.
RATE OF CLIMB on 3 engines at sea level—ft./min.	520	740
STALLING SPEED—flaps up—MPH	135.0	108.8
STALLING SPEED—flaps down—MPH	89.7	83.5
POWER REQUIRED for 200 MPH at 8,000 ft.—BHP	4 x 710	4 x 670

used. There has been a habit among pilots to lower the landing gear before lowering the flaps in practically all cases. It is believed that this tendency has been the result of carrying over fear of forgetting landing gear extension from the time when retractable landing gears were rather undependable. Now that they have been improved so greatly and warning devices incorporated to remind the pilot to lower the landing gear, it can be expected that the pilots will often use a moderate amount of wing flap when doing any maneuvering at low speeds. This should be particularly true on new aircraft because of the excellent climb with flaps extended. Fig. 30 shows the effect of various components of the airplane in changing the rate of climb at different airspeeds. It will be seen that at 120 miles per hour an extended tricycle landing gear will reduce the rate of climb approximately 260 feet per minute while at 90 m.p.h. the reduction is 100 feet per minute. When the maneuvering flap setting is used the rate of climb is decreased by 200 feet per minute. Inasmuch as the normal rate of climb with wing flaps retracted is 1640 feet per minute, this sacrifice of rate of climb is relatively unimportant.

In regard to other changes in pilot technique, the most important will be in using the flaps for take-off. No particular problems should arise here, although with normal type of landing gears there was a good deal of reluctance to use flaps for this purpose. This came about because the older type airplanes with a standard landing gear were subjected to a considerable amount of vertical tail blanketing when flaps were extended and also in certain cases turning tendencies were developed due to this slipstream reaction on the wing flaps. Both of these conditions can be largely eliminated by the use of a tricycle landing gear in which the vertical tail is lifted clear of the air flow away from the flap during take-off. Also the tricycle gear with its greater stability can neutralize the turning tendency until the airspeed over the vertical tail builds up.

Economic Factors

All factors affected by increasing wing loading work toward lower operating costs. The problem of hangar or storage space for future transports makes the absolute size of the airplane an important factor. One look at Figs. 1 and 2 will indicate the advantage of higher wing loadings from this point of view.

Present Restrictions

At the present time, the United States is the only country that has a definite restriction on landing speed. To arbitrarily restrict designers from using rational rather than arbitrary requirements on airplane performance seriously hinders a healthy state of design improvement to obtain many of the advantages given above. The landing safety of an airplane is not determined solely by the speed at which it contacts the ground, but rather by its controllability and stability

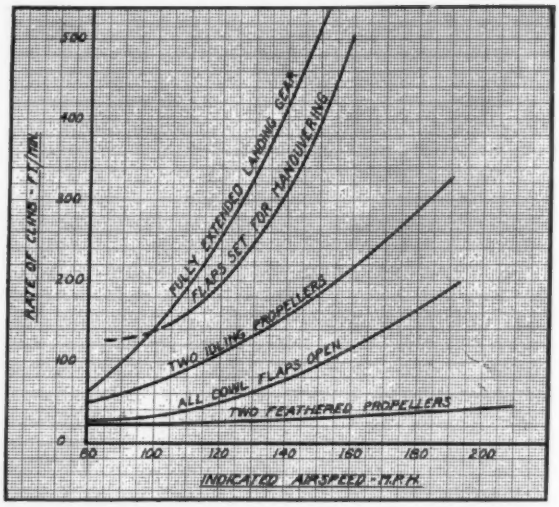

FIG. 30. Loss of rate of climb, at sea level, due to various airplane parts—four-engined airplane "C." Weight 40,000 lbs.

both in the air and on the ground. Perhaps it would be well to point out that present day airplanes are landing as fast or faster than the values referred to in this paper, primarily due to the fact present day aircraft fall far short of the desirable requirements in regard to stalling characteristics.

Conclusions

From the preceding study, the following conclusions may be drawn:

1. *The use of increased wing loading* is fully justified on a basis of improved performance, range and better economy.
2. *Increased wing loading* will lead to airplanes with lower first cost and smaller size, both of which have important effects on operating economy.
3. *The slight increase in landing speed* will not be obtained at a reduction of landing safety due to improvements in stalling characteristics, control, stability and landing gear improvements.
4. *The problem of icing* is no more severe for the airplane with heavy wing loading than it is for one with light wing loading. The advantages of higher initial rate of climb, higher speed and greater range still remain with the heavily loaded airplane, even under severe icing conditions.
5. *The icing problem* is relatively less severe on large airplanes than on small ones. Research now being undertaken by the various manufacturers and government testing agencies will lead to substantial improvement in performance under icing conditions. This will further justify the use of increased wing loading.
6. *Flight characteristics* now common in large airplanes should not be considered as necessarily applying to future designs when changes in safety regulations are considered.

Experimental Determination of Hydrodynamic Stability

ERNEST G. STOUT

Consolidated Aircraft Corp.

SUMMARY

The ability to predict hydrodynamic stability by some simple experimental means, analogous to wind tunnel testing, is of great importance to the manufacturer of flying boats and seaplanes. Such a method is outlined which involves the testing of a dynamically similar tank model. The characteristics and construction problems of dynamic tank models are considered as well as a general discussion of the testing technique.

While further improvements in methods and equipment are discussed, it is concluded that the present development is adequate for the determination of the range of stability and the proper location for the step. These conclusions are substantiated by the results of full scale correlation.

INTRODUCTION

A HYDRODYNAMICALLY stable seaplane is one which shows no inherent tendency to oscillate in heave, pitch, or yaw, or combinations, while taking off or alighting upon the water with any normal condition of loading or attitude. Lack of stability as a result of the first two types of oscillation is the phenomenon commonly known as "porpoising."

In recent years porpoising has become a major problem in design because of the definite trend toward higher wing and beam loadings. Two excellent theoretical and mathematical treatments of the subject by Perring and Glauert[1] in England and Klemin, Pierson and Storer[2] in the United States have been published. However, they have not presented to the manufacturer an adequate, simple or direct means of predicting the stability characteristics of new designs. As a result large sums have been expended and delays experienced while attempting to obtain satisfactory full scale stability with cut and try methods.

While investigating the subject of porpoising the author was impressed by the simplicity and directness of a method developed by the English and described by Coombes, Perring and Johnston in *The Use of Dynamically Similar Models for the Determination of the Porpoising Characteristics of Seaplanes*,[3] British R. & M. 1718. By an extension and refinement of the English method and equipment, a means of tank testing has been developed whereby the manufacturer can determine rapidly, and at a relatively small cost, the hydrodynamic stability characteristics of a proposed design through the use of a dynamically similar model.

The same model, less the air structure, has sufficient strength and permanence of dimensions to withstand the loads and maintain the accuracy required of the usual resistance tests conducted with the conventional tank model. A dynamic model will cost approximately 50 per cent more than the normal tank model, but due to the fact that a bare hull does not indicate the true behavior of the full scale airplane, the added value of the dynamic model justifies the additional expense.

The usual bare tank model is an accurate but very heavy reproduction of the hull only, the correct mass distribution and all aerodynamic forces being neglected. From such a model only the geometric form characteristics are obtainable, *i.e.*, hydrodynamic resistance, moment, and wave form due to shape.

On the other hand, a dynamic model has the following characteristics in common with the full scale airplane which make attainable not only the geometric but the dynamic properties as well:

(1) The hull, particularly below the chine, is reproduced accurately to scale.
(2) The air structure is reproduced accurately in section and planform.
(3) The total gross weight is to scale.
(4) The center of gravity position is geometrically to scale.
(5) The pitching moment of inertia, *i.e.*, the mass distribution, is to scale.

The characteristics, construction, testing technique and results of dynamic testing will be discussed.

MODEL CHARACTERISTICS

The fundamental characteristic of a dynamic model is the reproduction of all full scale motions in pitch and heave. It has been customary in the past to test a geometric reproduction of only the hull of the airplane in a towing tank and to represent the lift due to the wing by either a hydrovane running in the water or a system of counterbalance weights. This force was applied to the center of gravity of the airplane by means of a pulley or linkage mechanism. In practically every case the weight of the model and towing gate has caused the mass moving vertically to greatly exceed the scale gross weight of the airplane being tested.

This condition of dissimilarity coupled with excess inertia and the absence of aerodynamic moments and damping made the model unreliable as a source of in-

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formation on full scale behavior. For example, it was possible to determine the optimum center of gravity position for minimum resistance but there was no assurance that such a location was the optimum, or even acceptable, from a stability standpoint. Very often the latter criterion is extremely critical in the full scale airplane and frequently necessitates a shift that is detrimental to the resistance. Tank tests have shown that very often a small shift in center of gravity will increase the hull resistance as much as 25 or 30 per cent. For these reasons it is advantageous to conduct stability tests in conjunction with the determination of resistance.

From the laws of dimensional similarity, the following fundamental relations are derived: (1) Gross Weight $\propto \lambda^3$, (2) Velocity $\propto \sqrt{\lambda}$, (3) Time $\propto \sqrt{\lambda}$, (4) Moments $\propto \lambda^4$, and (5) Moments of Inertia $\propto \lambda^5$. λ equals the scale.

It follows from these relations that the water and air forces will be to scale, provided the structure is geometrically and aerodynamically similar. Due to aerodynamic scale effect, the maximum lift of the wing will not be exactly to scale. Some compensation for this loss can be made by increasing the flaps to 100 per cent span. However, for actual take-off and landing studies it is necessary to reduce the gross weight slightly to obtain scale getaway speed. As the effect of Reynolds Number is to extend the upper portion of the lift curve, the lift throughout most of the run up to getaway will be to scale. Prior to starting the stability tests it is necessary to check the elevator effectiveness which usually requires an addition to the movable area or provision for stabilizer movement in conjunction with the elevator. Upon application of the above corrections the aerodynamic characteristics of the model will bear a reasonable similarity to full scale.

While it is comparatively simple to obtain the correct model weight and balance, the mass distribution presents a more difficult problem. The pitching moment of inertia (mk^2) varies with the fifth power of the scale and can only be obtained by shifting mass in the model.

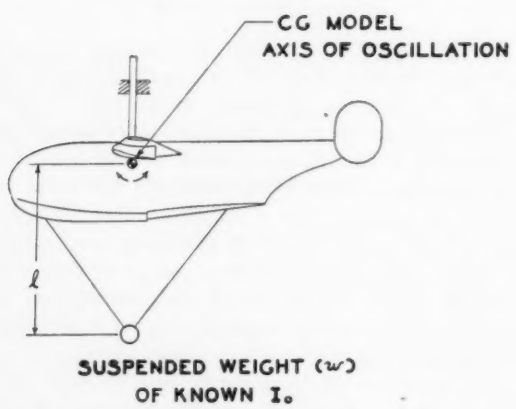

FIG. 1. Compound pendulum swinging gear for the determination of pitching moment of inertia.

In order to obtain the correct value, it is usually necessary for at least one-half of the total gross weight of the model to be lead ballast with the center of gravity of the model, less ballast, at approximately the correct location. This necessitates particularly light construction in the tail.

The pitching moment of inertia is determined experimentally by a method developed at the N.A.C.A. whereby the model is swung as a compound pendulum (Fig. 1) while the period is timed with a stop watch. By suspending a weight of known mass and inertia at a known length below the center of gravity of the model and oscillating the system about the center of gravity, the pitching moment of inertia of the model can be determined from the following formula:

$$I_{0_{\text{model}}} = wl\left(\frac{T^2}{4\pi^2} - \frac{l}{g}\right) - I_{ow}$$

where: $I_{0\ \text{model}}$ = pitching moment of inertia of the model about its center of gravity, slugs feet^2

w = weight of suspended weight, lbs.

l = distance from weight to c.g. of model, ft.

T = measured period of pendulum, seconds

g = acceleration due to gravity, 32.2 ft./sec.^{2}

I_{ow} = moment of inertia of suspended weight about its own axis, slugs feet^2

With the inertia of the full scale airplane known, the required period for the model can be computed. It is then necessary to shift the ballast and swing the model until that period is obtained. The timing of fifty oscillations from a model displacement of three or four degrees has been found to be adequate for a determination of I.

Model Construction

In order to obtain the correct pitching moment of inertia it is necessary to have approximately one-half of the weight of the model in lead ballast. This requires the structure to be extremely light, yet it must have sufficient strength to withstand the most severe porpoising likely to be encountered. To meet the above requirements balsa monocoque construction has proved to be the most satisfactory. Figs. 2 and 3 show two typical dynamic models whose construction will be briefly outlined. This is followed by a description of the equipment and methods used for open water testing.

The wing, shown in Fig. 4, is of full cantilever, built-up, stressed skin construction. Mahogany was employed for the leading and trailing edges interconnected with $^1/_8$-in. three-ply pine bulkheads spaced approximately five inches apart. Spruce stringers were used in the center section and balsa webs were employed out-

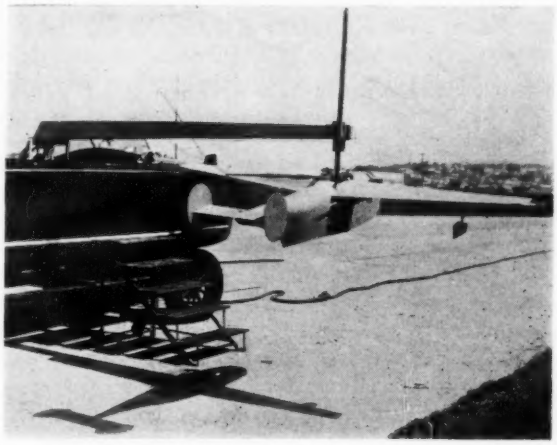

FIG. 2. Typical dynamic tank model mounted on speedboat for testing.

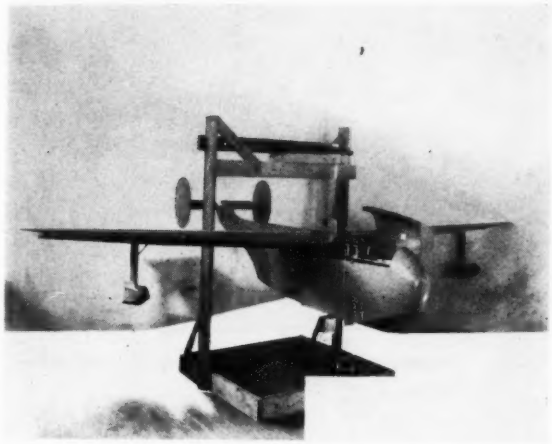

FIG. 3. Typical dynamic tank model mounted in inertia swinging gear.

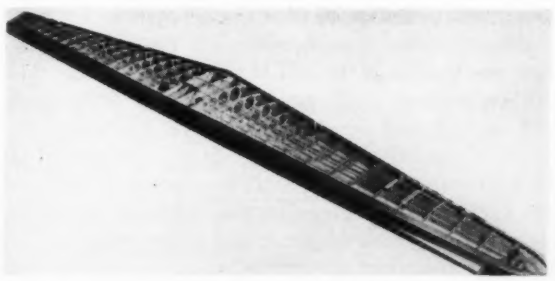

FIG. 4. Construction of typical dynamic model wing.

board to the wing tips. The structure was planked with narrow strips of balsa sheet and thoroughly doped. Japanese rice tissue paper was doped to the planking to seal the extremely porous balsa. Two coats of pigmented lacquer were sprayed on which gave a very smooth, spray-resistant finish.

Fig. 5 shows a typical hull which was built around a continuous mahogany centerline upon which were mounted $^1/_8$-in. three-ply pine bulkheads at each full scale bulkhead and beltframe station. Provisions were made in the hull bottom for portable sections to facilitate modification of variables such as step position, step depth, angle of afterbody keel and other related items. Regions of abrupt curvature, such as the extreme bow and stern, were made of solid balsa. While held in the jig, the skeleton was planked with narrow strips of balsa sheet. The hull was then removed and the bottom laminated with three layers of thin balsa sheet which eliminated the necessity for stringers. Sharp edge discontinuities such as the step and chine were made of mahogany. The entire structure was given a heavy coat of varnish, inside and out.

To obtain a high gloss finish and to completely seal the porous balsa the exterior of the hull was covered with Japanese rice tissue paper. The paper was attached to the varnished balsa with shellac and rubbed out smooth. The sealed hull was then sprayed with three light coats of pigmented varnish and rubbed to a high gloss. This type of construction and finish gave an extremely strong hull of low weight which was impervious to water. Tests have shown excellent permanence of dimensions after as much as six hours of continuous high speed testing.

The tail surfaces were of conventional spar and rib construction. They were covered with a high grade silk and doped. In Fig. 2, the stabilizer and elevator were moved as a unit. This was later discarded in favor of the method shown in Fig. 3, where the elevator hinged as in full scale and was operated by a flexible wire cable. The vertical surfaces were fixed and were reproduced to scale in planform only. Their function was to relieve the yaw restraint of the towing fitting by giving the model directional stability.

In Fig. 2 the lead ballast was carried externally on two dural T monorails which were located near the vertical center of gravity position. However, due to objectionable interference effects, this was modified as shown in Fig. 3. In the latter case, the lead was carried internally upon two dural tracks which were parallel to the base line. Means were provided for clamping the ballast at any desired fore and aft location. Vertical center of gravity adjustment was obtained by inserting wood dowels between the lead and the tracks. A vernier vertical adjustment was located on the trim indicator which greatly expedited the balancing operation. In order to change the horizontal location of the center

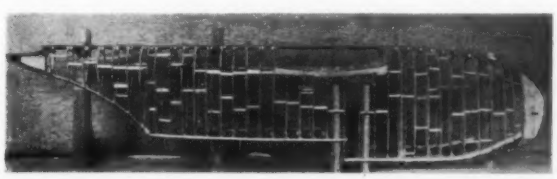

FIG. 5. Construction of typical dynamic model hull.

of gravity it was only necessary to relocate the pivot and drop the vernier weight, giving the model pendulum stability. The model was then statically balanced horizontally by sliding the ballast on the tracks. Upon obtaining static horizontal balance, the vernier was returned to its original location, which brought the model back to the correct vertical balance. Ballast tracks were also located in the afterbody so that variations in the moment of inertia could be made. All excess ballast which was necessary to obtain scale gross weight was attached to the towing staff, which in effect placed it directly at the c.g. of the model.

Towing Equipment

The value of a dynamic model depends upon its ability to simulate the motions of the full scale airplane. To do this properly, the model should be capable of self-propulsion under free flight conditions. For apparent reasons such as weight, difficulty of control, and extreme complication, this is not feasible. The compromised towing system illustrated in Fig. 2 was designed to approach the ideal condition as nearly as possible without seriously affecting the accuracy of the results.

The fundamental motions involved in porpoising are various combinations of pitch and heave. Therefore, it is assumed that restraint in yaw and roll can be applied without appreciable adverse effect. It has been established by full scale tests that the motions under consideration originate from moving instantaneous centers of oscillation which usually lay aft of and below the center of gravity of the airplane. However, for simplicity and convenience, the towing fitting was designed so that the model would rise vertically, and pitch, about the center of gravity. As the only physical connection from the means of propulsion to the model was the attachment at the center of gravity, it was necessary to transmit the thrust through that point. The eccentricity between the thrust line and the center of gravity was compensated for by applying a constant equivalent thrust moment to the model by means of a static weight. The aerodynamic dissimilarity due to the absence of the slipstream has been covered elsewhere in this paper. In spite of these compromises it has been established through extensive dynamic testing and correlation with full scale that, while the model cannot accurately reproduce the motions of the full scale airplane, it does give an equivalent motion which has been found to be adequate for the prediction of full scale stability.

Fig. 6 is a diagrammatic sketch of the center of gravity fitting which allowed a wide range in longitudinal center of gravity movement. The square towing staff was pivoted to this fitting which allowed freedom in pitch about the center of gravity. The fitting was mounted in the hull on a longitudinal axis which allowed freedom in roll. The freedom in roll was

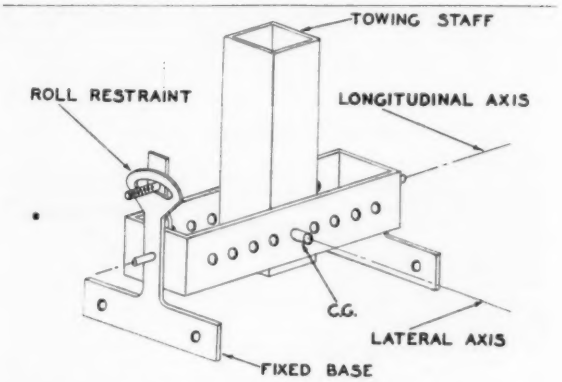

Fig. 6. Typical center of gravity fitting for dynamic models.

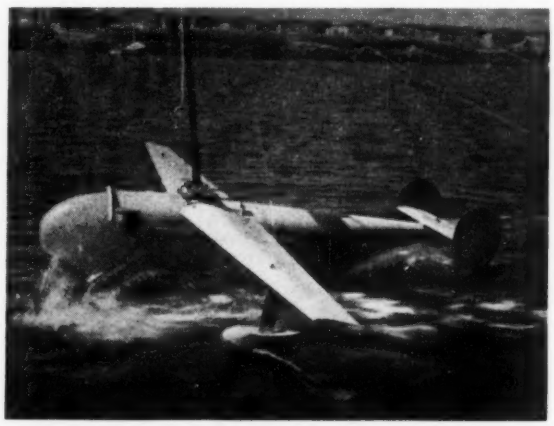

Fig. 7. Dynamic model test to determine float characteristics.

required only when investigating the characteristics of floats during take-off; otherwise the fitting was locked about the longitudinal axis which restrained the model in roll. Fig. 7 shows the model being tested with freedom in roll to determine float characteristics.

A square roller cage, consisting of twelve ball bearings, was located at the end of the towing boom. The ball bearings bore on the machined surfaces of the square staff and allowed freedom in rise, yet restrained the model in yaw without binding. Stops were placed on the trim scale and staff to limit the amount of trim and rise, respectively. A hoisting pulley was placed on the boom which permitted the model to be pulled out of the water at the end of each run.

The towing boom was a plywood cantilever beam of triangular cross-section. The length was determined so that the model would clear the bow wave of the speedboat* and run in undisturbed water. The root of the boom was bolted to a steel tube frame which was secured to the floor of the boat. Guy wires from the boat to the end of the boom completed the installation.

* The author wishes to acknowledge the cooperation of the U. S. Coast Guard in furnishing the speed boat used in these tests.

While this discussion has dealt primarily with open water testing, the same principles and conclusions apply equally as well to tests conducted in a towing basin. The towing basin has the advantage of more uniform year-round conditions, greater control over variables such as speed, and the availability of shops. However, an outstanding disadvantage, other than increased cost, is the reduction in air velocity in the vicinity of the model due to the ramming effect of the carriage. This reduction in speed seriously aggravates the loss in lift due to scale effect. Because of this reduction in aerodynamic q the tank tests are actually equivalent to downwind operation. On the other hand, in open water testing any ratio of air and water speed may be obtained by carefully choosing the location and time of day for the tests.

Testing Technique

There are two methods for determining the stability characteristics of a flying boat. The first, which is the older of the two methods, is described by Coombes, Perring and Johnston,[3] and given practical applications by Johnston and Tye[4] and Perring and Hutchinson.[5] The technique they developed consisted of a series of constant speed runs wherein the maximum and minimum trim that could be attained, without instability, was determined. The results of such an investigation are usually plotted in the form shown in Fig. 8a. The

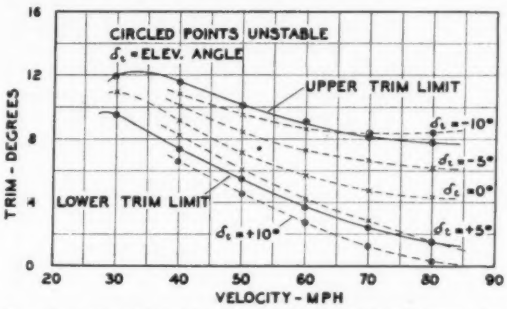

Fig. 8a. Typical plot of the data obtained from the constant speed method of testing.

second method, which was developed by the author, consists of a series of accelerated runs to getaway, each followed by an actual landing, wherein the center of gravity is moved until the limiting fore and aft location is determined. The second method is usually plotted in the form shown in Fig. 8b. For a complete investigation, both methods should be utilized.

Trim has been found to be a relatively unimportant and very difficult parameter to readily establish full scale. As the first method is based upon trim as a parameter, it becomes difficult to translate the results into actual practice. The procedure for determining the trim limits by constant speed running is long, and upon reaching the unstable region it is difficult to determine the true character and relative magnitude of the instability.

To offset these disadvantages and to provide a more rapid means for determining stability characteristics the second method was developed, which is based upon accelerated motion. In all flying boat designs, the range of center of gravity travel for various loading

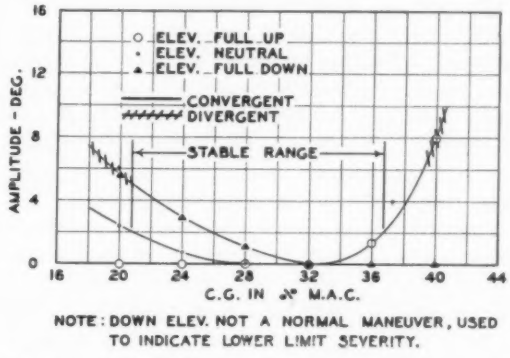

Fig. 8b. Typical plot of the data obtained from the accelerated motion method of testing.

conditions is very carefully controlled. It is essential that the airplane be hydrodynamically stable for all center of gravity locations within the normal range. Therefore, to aid in rapid correlation between model and full scale, it appeared that center of gravity location was the logical parameter to use from a practical point of view. The basic requirement for this method is that the aerodynamic control derived from the elevators be carefully corrected to the equivalent full scale value which may require as much as a 40 per cent increase in elevator chord. The runs consist of accelerating the model to getaway and landing it just as in full scale. With this method it is possible to note the speed at which instability occurs, whether the oscillation is divergent or convergent with speed, and the amplitude of the oscillation. By progressively moving the center of gravity fore and aft, the stable range of stability with center of gravity movement can be determined.

One of the most important uses for the dynamic model in practice is to determine the correct step location for a given design. As noted from the following discussion, this can be accomplished very readily with the accelerated run method. For example, assume that the given design has a range of center of gravity movement extending from 22 to 30 per cent of the mean chord. Upon testing the model, it was found that forward of 25 per cent and aft of 34 per cent of the mean aerodynamic chord the model was unstable. This would indicate that the range of stability was sufficient but that it fell outside of the design limits. In a case of this nature it is not necessary to increase the stability of the airplane but merely to adjust the available stability so that it may be fully utilized. This condition usually results from an incorrect step location and tests have shown that within reasonable limits, center of gravity movement can be exchanged for an equal step movement. Returning to the basic assumption, the

step on the model would be moved forward $3^1/_2$ per cent of the mean aerodynamic chord and rerun for a check. Experience has found that the stable range previously determined as extending from 25 to 34 per cent would now be bodily moved forward to approximately $21^1/_2$ to $30^1/_2$ per cent of the mean aerodynamic chord which would bracket the desired range of center of gravity movement. As the maximum elevator control has been calibrated against full scale, it is not necessary to further correlate trim between the model and the full size airplane. For tests of this nature an arbitrary ± one degree oscillation is considered to be the limiting degree of instability for satisfactory operation.

If instead of a stable range of center of gravity positions extending from 25 to 34 per cent of the mean aerodynamic chord, the model had shown a total range much less than this, it would have been necessary to modify the hull until the range was broadened the desired amount before attempting to correctly locate the step. During this procedure it is advantageous to run the model at constant speed until the limits imposed by trim have been improved. Upon obtaining a definite improvement in stability the c.g. limits should be checked. While making modifications to improve the hydrodynamic stability, it is desirable to make frequent checks on the center of gravity range; for modifications which improve hydrodynamic stability, such as deeper steps, sharp chines, increased beam, revised lines, etc., very often are deterimental to aerodynamic drag. From a practical consideration there is no need for obtaining stability at the expense of aerodynamic performance beyond the limits of service operation.

In open water testing, a moving picture camera is mounted in the speed boat which records each run. The camera runs at a constant speed of 24 frames per second which is correlated with the engine tachometer to give the time and speed relation. The trim and rise, period and amplitude of oscillation, and, if desired, accelerations in pitch and translation may be determined by analyzing the film in a shadow box, one frame at a time. In all cases, the horizon is used as the horizontal reference line. Fig. 9 shows a typical stability plot from a series of accelerated runs. If accelerations in pitch and translation are desired, the trim and rise data are plotted against time, and the second derivative of these curves gives angular acceleration in radians per sec. per sec. and ft. per sec. per sec., respectively.

The shadow box used in the analysis is a black box with a Leica projector at one end and a ground glass screen at the other. A strip of vellum moves across the ground glass screen upon which the necessary reference lines are traced from the projected image. Sketches of critical spray and wave patterns are made in the same manner for comparison and record purposes.

Full Scale Correlation

All methods of fundamental research which involve basic assumptions and comprises with theory should be justified with rigorous experimental correlation. Over a period of three years, the method of dynamic testing

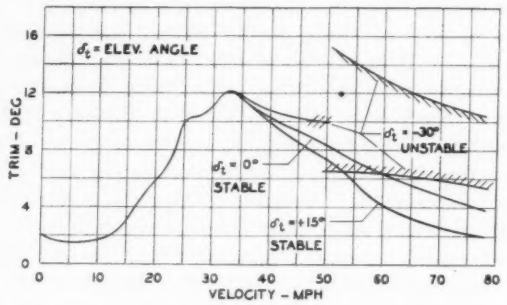

FIG. 9. Typical plot of stability from photographic recording.

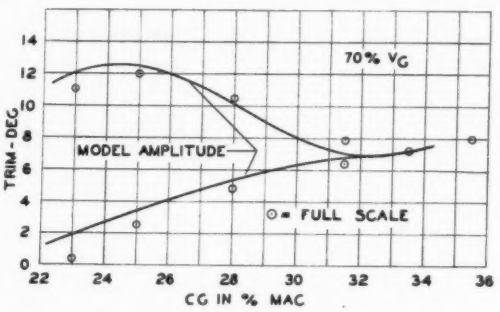

FIG. 10. Correlation plot showing effect of center of gravity movement.

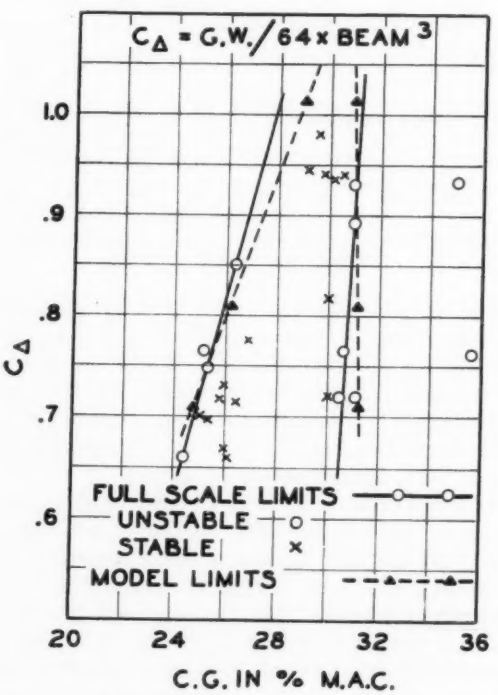

FIG. 11. Correlation plot showing center of gravity limits *vs.* load.

described in this paper has been carefully correlated with three modern, full scale, flying boats. These tests have involved various degrees of instability, modification to lines, and relocation of step position. In every case, without exception, the model has predicated the degree of stability and adjustment necessary within the limits of practical consideration. Center of gravity limits and step locations for all combinations of loading have been checked within the accuracy of full scale determination.

As these investigations have been upon projects confidential in nature, it is not possible to reproduce them here in full. However, Figs. 10 and 11 present sample plots of these results taken at random. Fig. 10 is a plot showing the effect of center of gravity movement at a constant load. Fig. 11 is a composite plot showing model and full scale center of gravity limits *vs.* load. While the true motions themselves are not faithfully reproduced, the equivalent motions are found to give exceptionally accurate results upon which to base design criteria. It is the author's belief that dynamic model testing along the lines suggested in this paper will go far toward eliminating the long and costly delays caused by the phenomenon known as porpoising.

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[1] Perring, W. G. A., and Glauert, H., *Stability on the Water of a Seaplane in the Planing Condition*, British R. & M. No. 1493, September, 1932.

[2] Klemin, A., Pierson, J. D., and Storer, E. M., *An Introduction to Seaplane Porpoising*, Journal of the Aeronautical Sciences, Vol. 6, No. 8, page 311, June, 1939.

[3] Coombes, L. P., Perring, W. G. A., and Johnston, L., *The Use of Dynamically Similar Models for Determining the Porpoising Characteristics of Seaplanes*, British R. & M. No. 1718, November, 1935.

[4] Johnston, L., and Tye, W. D., *Effect of Differences of Form on the Porpoising Characteristics of Two Flying Boats*, British R. & M. No. 1777, October, 1936.

[5] Perring, W. G. A., and Hutchinson, J. L., *Full Scale and Model Porpoising Tests of the Singapore IIc*, British R. & M. No. 1712, November, 1935

Measurements on Detonation in Duchêne Apparatus

G. BROERSMA*

SUMMARY

Measurements on the Duchêne apparatus[1] were made at the "Proefstation Delft" to investigate whether the mechanism of detonation with this apparatus differed from that found with the "Delft" window engine.[2]

The experimental results consisted of flame pictures, pressure diagrams and ionization diagrams.

The results are discussed in terms of the literature, and two mechanisms of detonation are indicated, *viz.*:

(1) The mechanism defined as physical detonation, *i.e.*, by physical processes of aerodynamic flow, mixing and diffusion a critical stage is reached at which the speed of the flame front changes from the normal subsonic rate to a supersonic rate.

(2) The mechanism defined as chemical detonation, *i.e.*, by chemical processes of chain reactions in the end-gas a critical stage is reached in which the end-gas ignites at one or more points. From these points combustion proceeds at normal, subsonic speeds.

Each of the two mechanisms has its own time constants, depending upon thermodynamic, chemical and geometric conditions. They may under circumstances overlap, that is, when chemical detonation has started, physical detonation may still occur, but not the opposite.

Both of these mechanisms may occur in the Duchêne apparatus. In the window engine chemical detonation is usual, as in most engines, although a phase of physical detonation may sometimes be indicated. In tubes and bombs physical detonation generally occurs, although chemical detonation may sometimes be indicated.

INTRODUCTION

CONTEMPORARY theoretical approaches to the problem of detonation in engines may be classified as follows:

(a) Detonation in engines may be identical with that found in tubes: under certain conditions the speed of the flame front suddenly increases to speeds greater than that of sound; this would occur under the thermodynamical conditions required by Jouguet's theory.[3]

(b) Detonation in engines may be a phenomenon occurring primarily in the end-gas by self-ignition of a finite portion of the latter, causing an explosion, *i.e.*, for a combustion where heat is produced at such a rate that transport of energy by convection and radiation is replaced primarily by transport of energy by diffusion, resulting in a detonating combustion wave.[4]

(c) Detonation in engines is a phenomenon occurring primarily in the end-gas by self-ignition of infinitesimally small volumes at one or more points ahead of the flame front, creating one or more flame fronts proceeding at normal, subsonic speeds.[5]

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* Technical Department, Navy Airport, Sourabaya, Dutch East Indies. (Formerly "Proefstation Delft," Royal Shell.)

Whereas most experimental investigations show that the phenomenon mentioned under (c) occurs in engines, some measurements seem to indicate that that mentioned under (a) may also exist.[6] An explanation of the high values of the measured speeds is possible by taking into account the direction in which the combustion spreads with respect to the slot through which the flame was observed and photographed.[7]

Duchêne also appears to have found in his single combustion apparatus the phenomenon of detonation as originally observed by Berthelot and Vieille[8] and investigated by Mallard and Le Chatelier.[9]

As the conditions employed by Duchêne resembled somewhat the conditions of the Delft window engine, in which ignition of the end-gas in an infinitely small volume at one or more points before the flame front was always found to be the primary start of detonation, a closer investigation and comparison appeared worth while. For this purpose the Delft laboratory was able to borrow the necessary Type 2 apparatus from Duchêne.

DESCRIPTION OF THE APPARATUS

Investigations were carried out on the second apparatus as described in the publication mentioned in reference 1. A cross-section of the apparatus proper may be found in Fig. 2. The following changes were made in the original apparatus.

(1) The fuel was dripped into the glass carburetor as shown in Fig. 1.

(2) One of the windows was first replaced by a steel plate containing 4 thermocouples, and later, spark plugs for ignition and an ionization gap were inserted at the positions originally occupied by the two outer thermocouples.

(3) A hole was drilled midway in one side of the combustion chamber and a pressure element was inserted; during the photographic recordings a spark plug was screwed into this hole (see Fig. 2a).

The resulting combustion chamber, as shown in Fig. 2, was used for the simultaneous ionization and pressure measurements.

OPERATION

The operation of the apparatus was carried out as follows: The cylinder was heated until a certain temperature was reached at one of the thermocouples (Fig. 2a) in the inside of the combustion chamber.

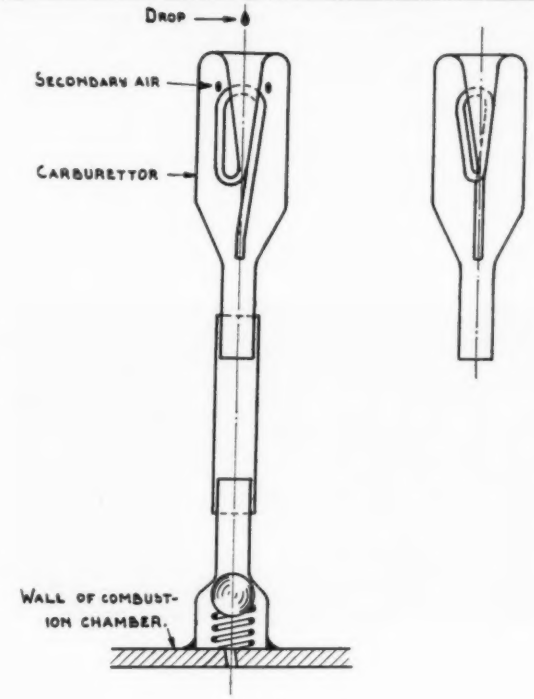
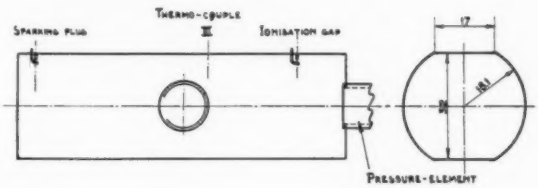


FIG. 1.



LOCATIONS OF:
SPARKING PLUG, THERMO-COUPLE, PRESSURE-ELEMENT AND IONISATION GAP, IN COMBUSTION CHAMBER IN DUCHÊNE-APPARATUS.

FIG. 2a.

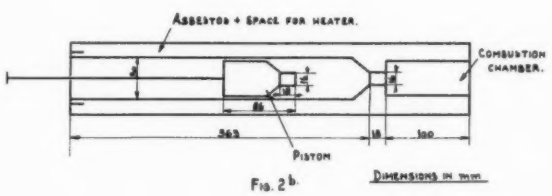


FIG. 2b.

FIG. 2.

The piston was pushed into the cylinder by hand until it seated. Then 4 to 6 drops of fuel were administered into the carburetor from a dripping apparatus.*

* The particular unit used appeared to give drops of the same volume irrespective of the fuel used; kerosene, petrol, benzene. The volume of a drop delivered was fixed at 0.0160 cubic centimeter. This unit was developed by Mr. Heitman, formerly of Royal Shell, but is not yet patented and is therefore not shown.

After that the piston was pulled out to the position comparable with the position of bottom dead center of an engine. Lastly a pressure of 11 to 12 atmospheres was suddenly released behind the piston by manually opening a cock. At the end of the stroke ignition occurred, *viz.*, when a ring on the outside end of the piston rod struck a lever manipulating the ignition circuit.

General Test Conditions

The apparatus is to be compared with an engine having a speed of 300 r.p.m., a compression ratio of 7 and a combustion chamber of 96 cc. volume.

During the photographic recording the test conditions were:

The mixture strength ranged from about 0.95 to about 1.55. (By mixture strength is meant the ratio of the amount of petrol actually present to the amount necessary for chemically complete combustion.)

The temperature, at the point inside of the combustion chamber wall, 58 mm. from the piston side (the combustion chamber having a length of 100 mm.), was 60°–140°C.

Fuels	Octane rating
Isooctane/*n*-heptane blends	0, 10, 20, 30, 40, 50, 60, 70
A reference fuel	42½
Same reference fuel with benzene	50
Dutch commercial fuel (for automotive use)	70

During the simultaneous ionization and pressure measurements the test conditions were:

Mixture strength	1.38
Temperature at point III, with the arrangement of the combustion chamber as shown in Fig. 2a, except that the ionization gap replaced the spark plug shown, the spark plug replaced the pressure element shown, and the pressure element was halfway along the combustion chamber	75.6°–96.1°C.
Temperature at point III, with the arrangement of the combustion chamber as shown in Fig. 2a	81.0°–89.2°C. and 80.9°–93.1°C.

Flame Pictures

The first series of experiments consisted of the taking of flame pictures; rather at random in the beginning. The photographic apparatus contained a drum rotating at a speed of 492 r.p.m.; the circumference being 49.3 cm., the speed of a point of the circumference was therefore equal to 404 cm. per sec. Hence, 1 mm. on the film or drum corresponds to 2.47×10^{-4} sec. The arrangement of lenses was focused onto the mid-plane of the combustion chamber. The photographic paper employed was Agfa I.S.S. For some pictures Agfa Isopan Ultra was used, but this film did not show much improvement.

Each series of measurements consisted of five flame pictures taken consecutively on the same piece of paper. During each of the five measurements the number of drops administered from the dripping apparatus was the same.

A series of measurements was carried out for three mixture strengths, from about 0.95 to about 1.55, of each of the fuels mentioned above. Four, five and six drops of fuel were used.

The following results were obtained.

(a) Normal combustion.

Fuel: blend of 70 per cent isooctane and 30 per cent *n*-heptane, by volume.
Octane Number, O.N. = 70. Mixture strength, m = 1.16.
Temperature at point III, T_{III} = 130.5°C. See Fig. 3a, which is sketched from a photograph.

(b) Normal combustion with "combustion en bloc" at the end.

Fuel: reference fuel, O.N. = $42^1/_2$, m = 1.29, T_{III} = 99.4°C., see Fig. 3b.
Fuel: 89 per cent reference fuel and 11 per cent benzene, O.N. = 50, m = 1.28, T_{III} = 101.3° C., see Fig. 3c.

(c) Normal combustion turning into combustion at sonic or supersonic speed.

Fuel: petrol, O.N. = 70, m = 1.24, T_{III} = 66.5°C., see Fig. 3d.
Fuel: *n*-heptane, O.N. = 0, m = 0.95, T_{III} = 91.6°C., see Fig. 3e. (Here a sound wave is breaking away at the critical spot and going downward.)

(d) Sonic wave starting from the piston.

Fuel: blend of 10 per cent isooctane and 90 per cent *n*-heptane, O.N. = 10, m = 1.15, T_{III} = 108.5°C., see Fig. 3f.
Fuel: *n*-heptane, O.N. = 0, m = 1.14, T_{III} = 86.9°C., see Fig. 3g.

(e) Normal combustion and self-ignition of the end-gas (as in the Delft window engine).

Fuel: blend of 70 per cent isooctane and 30 per cent *n*-heptane, O.N. = 70, m = 0.95, T_{III} = 139.1°C., see Fig. 3h.

(f) Self-ignition before the spark occurs.

Fuel: blend of 70 per cent isooctane and 30 per cent *n*-heptane, O.N. = 70, m = 1.16, T_{III} = 136.0°C., see Fig. 3k. The bright spots in Figs. 3f to 3k are reflected images of the small mirror used for the visual observation of the flame.

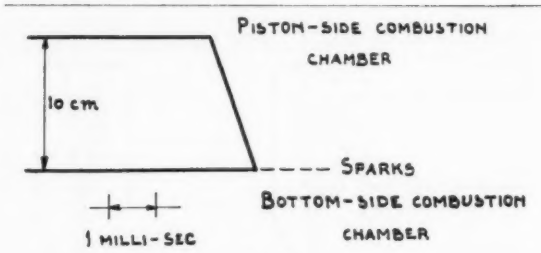


FIG. 3a.

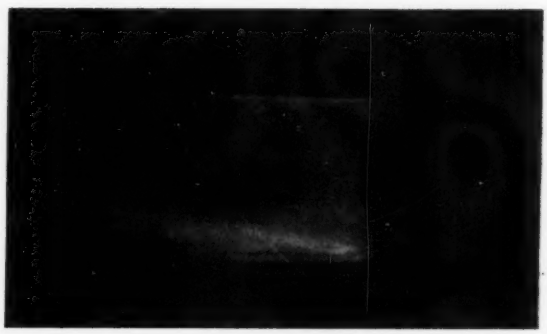


FIG. 3b.

FIG. 3c.

In an appendix speeds of sound in the unburnt gas are calculated for the cases of combustion mentioned under "Normal combustion turning into combustion at sonic or supersonic speed." The orders of magnitude of those speeds and the combustion speeds occurring in critical stages are shown to be the same, *viz.*, about 500–1100 meters per sec.

The gas vibrations are very easily started after an impact between two flame fronts, or a flame front with a wall. They also may occur with combustion and self-ignition of the end-gas at low values of the flame speed. The frequency of the vibrations is from 5400 to 5800 Hz.

The following kinds of combustion may be indicated: normal combustion, detonative combustion, normal combustion + self-ignition, pre-ignition. Detonative combustion occurs in a small region only.

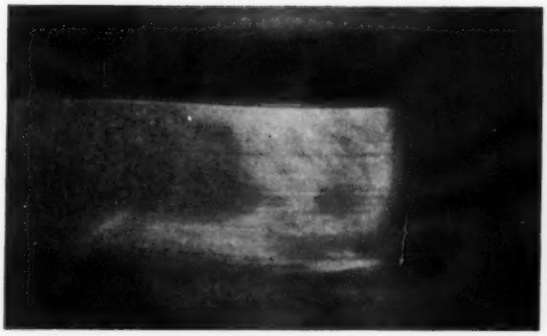


FIG. 3d.

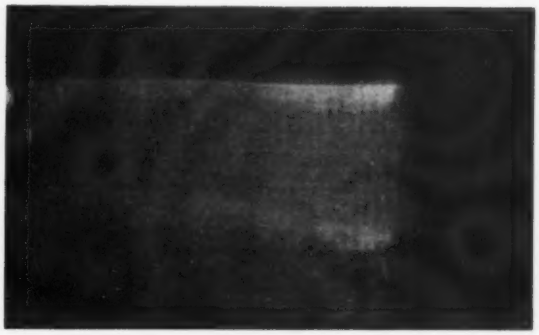


FIG. 3e.

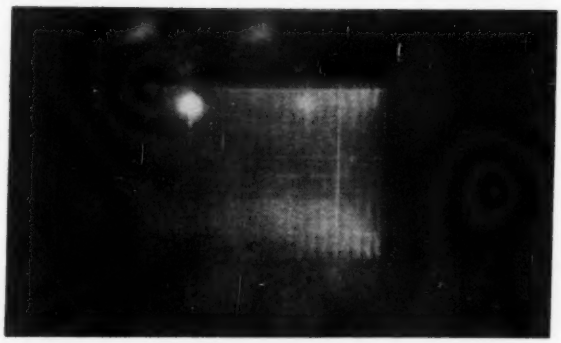


FIG. 3f.

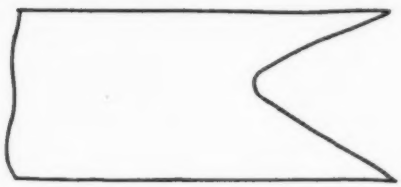


FIG. 3h.

FIG. 3g.

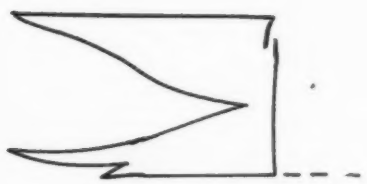


FIG. 3i.

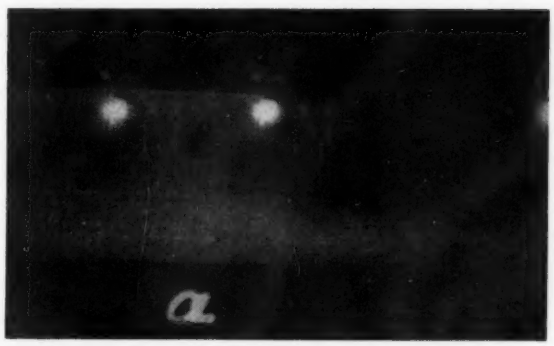


FIG. 3k.

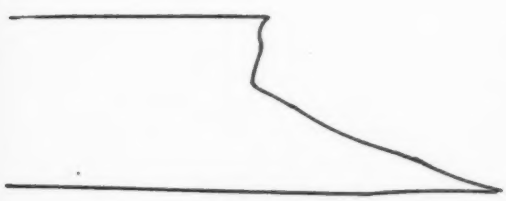


FIG. 3j.

There is sometimes a feature to be observed in flame pictures of real detonative combustion; a picture of normal combustion appears to be superimposed on a picture of combustion in a detonative wave. The combustion is far from being complete in the detonative wave (see Figs. 3d and 3e). Jouguet[10] calls this a partial detonation (détonation dissociée). Pressure records to be treated later revealed the same phenomenon.

Relative to the above summary of the different kinds of combustion found in the Duchêne apparatus, reference may be made to Serruys.[11]

(1) Normal combustion ("déflagration").
(2) Detonative combustion ("détonation propremement dite"), starting in the end-gas from a nucleus of finite dimensions (see introduction of this article).
(3) Pseudo-detonative combustion (self-ignition of the end-gas by hot spots).
(4) Self-ignition before the spark occurs ("auto-allumage").
(5) Vibrating combustion, the vibrations starting during compression.[12]
(6) Helicoidal combustion.[13]

Ionization and Pressure Diagrams

Schnauffer[14] studied flame propagation in engines by ionization gaps, which led Weinhart[15] to undertake his qualitative research of detonation in vessels and real engines by studying the character of the ionization diagram. The typical differences in ionization diagrams, found for the two cases of detonative combustion, correlated with differences in the pressure records taken simultaneously. (This idea of gaps dates back to Mallard and Le Chatelier.)

On the Duchêne unit the same experiments were made, using a 10 mm. spark plug as ionization gap (gap width 0.5 mm.) and the Delft quartz pressure element for the pressure recording. One hundred and fifty volts were impressed on a circuit with the gap, with 1 $M\ \Omega$ and a cathode ray tube in series. A General Electric cathode-ray tube was employed, whereas the pressure recording was done by a unit constructed by one of the laboratories of the Dutch Post, Telegraph and Telephone Company (P.T.T. unit). The sweep of the General Electric cathode-ray tube was coupled to that of the P.T.T. unit (the diagram length was 0.0204 sec.).

There were two arrangements of the positions of the ionization gap and the pressure element, as described above. Both arrangements gave the same results; correlation between pressure and ionization is apparent; the two diagrams show the same kind and sequence of characteristic features.

The aim was to localize the phenomenon of real detonation. Therefore the combination of fuel and mixture strength, which had shown a typical flame picture, was taken, *viz.:*

Fuel: blend of 10 per cent isooctane and 90 per cent heptane, $T_{III} = 75.6°$ to 96.1°C. and 80.9° to 93.1°C. (see Figs. 4 and 5), mixture strength = 1.38. A range of the temperature T_{III} was examined for typical pressure and ionization diagrams. The phenomenon was found in a small temperature range about 3°C. in width. The range varied in the neighborhood of 80° to 85°C., depending on circumstances which were not controlled, *e.g.*, humidity of the intake air, outside temperature and pressure as occurring on a certain day. Figs. 4 and 5 show photographs taken on two different days; the consecutive series of temperatures, $t_1 \ldots t_5$ should be considered apart for each figure.

Summarizing, the following typical combinations of pressure and ionization records were found (time increases from right to left):

(1) Normal pressure diagram together with a normal ionization diagram; temperature $T_{III} = t_1$°C.; see Fig. 5a ($T_{III} = 81.7$°C.).

(2) Continuous pressure diagram with vibrations together with discontinuous ionization diagram with vibrations; temperature $T_{III} = t_2 > t_1$°C., see Fig. 4a ($T_{III} = 85.6$°C.).

(3) Discontinuous pressure diagram with or without small vibrations together with discontinuous ionization diagram with or without vibrations; $T_{III} = t_k > t_2$°C., see Figs. 4b ($T_{III} = 89.0$°C.) and 5b ($T_{III} = 82.7$°C.).

(4) Continuous pressure diagram with vibrations in the ascending portion, with or without vibrations in descending portion together with discontinuous ionization diagram, with or without small vibrations afterwards; $T_{III} = t_4 > t_k$°C., see Figs. 4c ($T_{III} = 96.3$°C.) and 5c ($T_{III} = 90.6$°C.).

(5) Continuous pressure diagram with or without small vibrations in the descending portion, together with continuous ionization diagram without vibrations; $T_{III} = t_5 > t_4$°C., see Figs. 4d ($T_{III} = 90.0$°C.), 5d ($T_{III} = 87.7$°C.) and 5e ($T_{III} = 93.1$°C.).

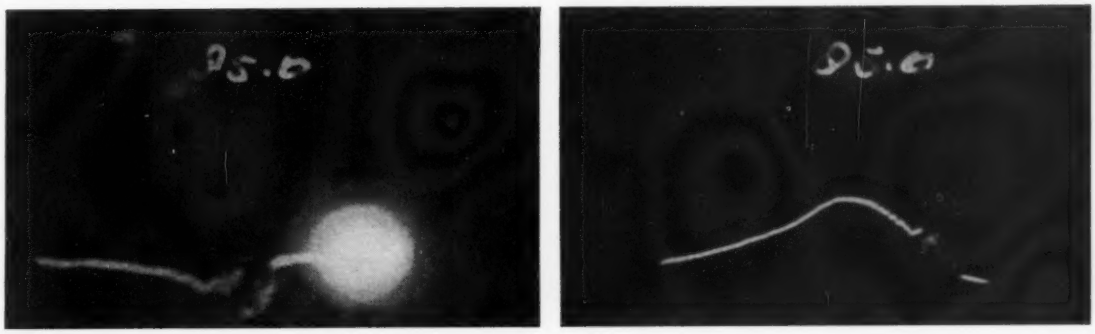
Weinhart also found a length of time base of about 2×10^{-4} sec. Fig. 4 of his article (a kind of relaxation curve) shows that the distance between two subsequent pressure peaks is about $^1/_4 \times 10^{-2}$ sec. The length of the pipe in which he experimented being 1 meter, this means that the pressure wave moved at an average speed of 500 meters per sec. This is in agreement with a velocity of 500 meters per sec. as computed in the appendix.

The order of magnitude of the pressures which were visibly recorded in the present diagrams is about 40–50 atmospheres. Higher values escaped recording as indicated by the discontinuous character of the pressure diagrams. Fig. 5d is typical; here the pressure diagram was swept off the cathode-ray tube. Weinhart actually measured values of 300 atmospheres.

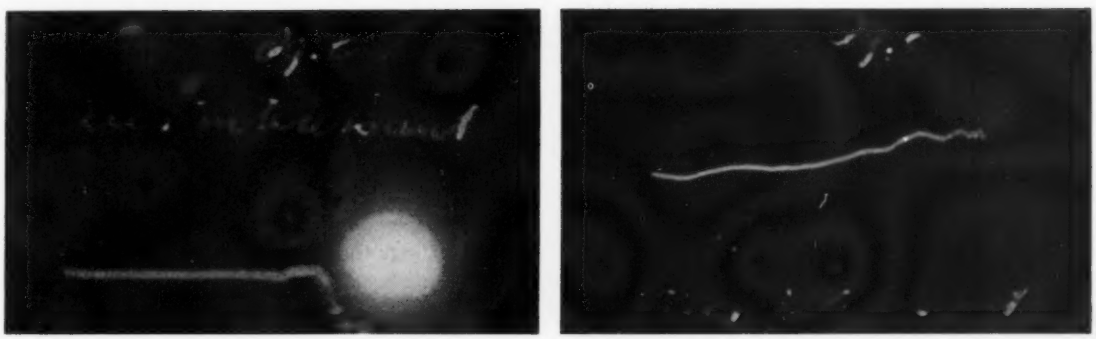
General Discussion

It is shown that physical detonation may occur in the Duchêne apparatus; actually the phenomenon has

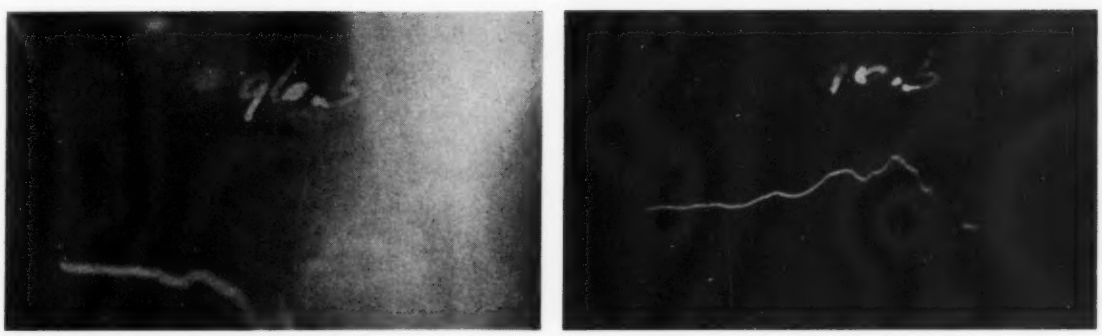
Ionization Pressure



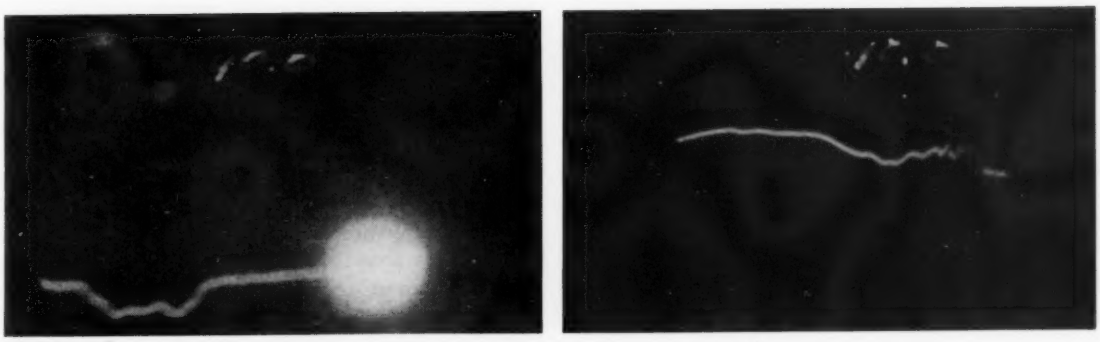
a.



b.



c.



d.

FIG. 4.

Ionization

Pressure

FIG. 5a.

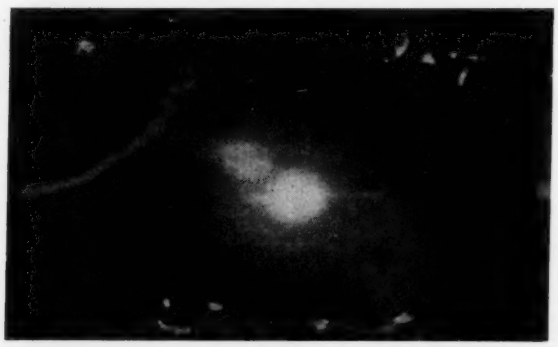


FIG. 5b. Swept from the tube. Pressure too high to record. Tube entirely smothered.

been localized in a narrow temperature range, *cet. par.* Repeated measurements show typical flame pictures, ionization and pressure diagrams in a very narrow temperature range. Analysis of the flame pictures shows that combustion is occurring at speeds comparable with those of sound in the end-gas, under the existing thermodynamic conditions. Comparison with Weinhart's experiments shows that the author found the same differences in ionization and pressure diagrams, indicating two kinds of detonative combustion. Theoretically, physical detonation occurs for one temperature range, *cet. par.*;* hence, experiment and theory are in good agreement.

* All other conditions remaining the same.

Moreover it appears as if the so-called "détonation dissociée" was again found, as mentioned above. In other words, a combustion takes place in which the detonative combustion is not complete. Superimposed on the detonative combustion is a slow normal combustion. The process may, for instance, be as given in Fig. 3e. The accompanying pressure and ionization records may then be as given in Figs. 4b, 5b and 5c. This particular kind of combustion occurs in the neighborhood of the real detonative combustion.

Relative to the correlation between photographic results and the ionization and pressure recording it appears that Figs. 3a; 3b, c; 3d, e, f, g; 3h; 3k correspond, respectively, with Figs. 5a; 4a; 4b, 5b; 4c, 5c; 4d, 5d, e.

From experiments similar to the above it might be inferred that detonation in engines is somewhat similar. While it is not impossible to devise an engine and conditions which may show the same phenomenon, something else is generally found.

Accepting the results of different experiments on combustion and knowing the conditions of these experiments one must try to build up a general view covering the experiments.

Starting with the phenomenon of detonation in tubes it has been remarked that the normal combustion always breaks into detonative combustion at the same spot, *cet. par.*[16] Gauze screens may change the position of this particular point, when they are placed before the point where the normal combustion has broken into detonative combustion. When placed behind this point, the screen is destroyed without influencing the position of the critical point, except when this occurs near the end of the tube.[17] This agrees with Véron's theories[18], based on experimental evidence, in which the apex of the curved flame front, at a certain point, is pushed back. The small volume first contains burnt gases, then becomes partly filled by fresh gases, while retaining some of the burnt gases. As a result of diffusion and flame movement near this apex, mixing of fresh and burnt gases occurs. The fresh gases, heated to a high temperature will burn so rapidly that energy is practically transported by diffusion. In the light of the kinetic theory of gases common combustion may be viewed as a transport of energy of the molecules by convection and radiation. As a result of the explosion a mass of molecules of higher impact values than before is given off into the molecules of the fresh gases and these are also ignited at a value of combustion speed comparable with the speed of the molecules. Evidence for this theory is given by Egerton's experiments mentioned in reference 16, in which the detonating flame front starts ahead of the existing one. This is supposition because the apex of the original flame front does not emit sufficient light to be photographed. The withdrawal at the critical point is not noticed therefore, whereas the subsequent explosion, at the point formerly filled by the apex, gives off sufficient light.

Ionization Pressure

FIG. 5c.

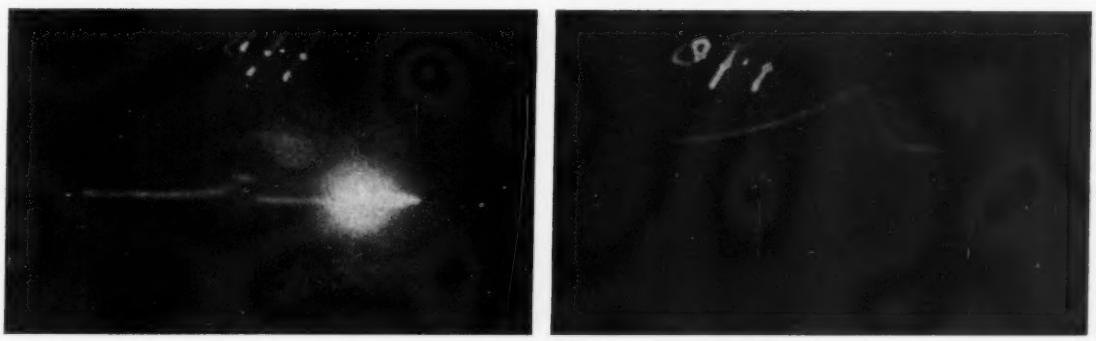


FIG. 5d.

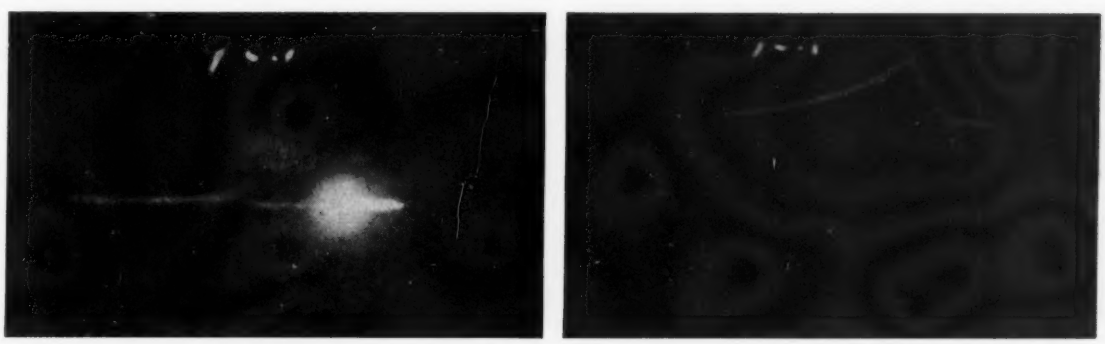


FIG. 5e.

Taffanal (see reference 10), a co-worker of Lafitte and of Bone and Fraser,[19] also accepts the idea that the diffusion from the flame front into the fresh gases changes in value at the critical point, so that combustion proceeds with molecular speeds. They do not explain how this is attained. The Russian scientists[20] are also working in this direction. In any case aerodynamical conceptions should be taken into account whatever kind of combustion is found. The influence of turbulence on combustion of any kind is well known.[21] Véron's dynamical theory together with Jouguet's statistical calculations may give the final solution for detonative combustion in tubes.

In engines the phenomenon of detonation is supposed to be either the same as that in tubes or due to self-ignition of the end-gas, which again may either cause combustion proceeding at a normal speed (Boerlage) or at a supersonic speed (Serruys). Serruys admits that a finite amount of end-gas burns simultaneously and causes an explosion as defined above. Jouguet conceives a process based on a theoretical temperature distribution in the burnt gas and end-gas; however, this process does not take account of dissociation and heat losses to the wall. By superimposing Serruys' local disturbance in the end-gas on the temperature distribution, Jouguet shows that a primary flame front of sufficient and finite width develops into an explosive combustion.

Conclusions

It is concluded that there are two mechanisms of detonative combustion. Each has its own critical stage and its own time constants. One is physical, the other is chemical.

The physical phenomenon of detonative combustion is the detonation occurring generally in tubes, bombs and other vessels. By physical processes of aerodynamical flow, mixing and diffusion, a critical stage is reached from which the flame front proceeds at supersonic speed. This phenomenon has its definite time constants. The occurrence of the critical stage at a certain point depends upon the width of tube,[12] the pressure,[22] and upon whether the tube is open or closed.[22]

Temperature has little influence and anti-knock agents have little or no effect.[16,22]

Lewis and von Elbe[12] describe experiments on detonation with tubes of different diameters. The distance between the ignition spark and the critical point at which the flame front breaks away at supersonic speed increases approximately linearly with the diameter. The larger the diameter the larger the distance required for the development of the supersonic flame velocity.

Increasing initial pressure brings about earlier detonation, up to a certain limit. Beyond this limit a further increase makes little difference (Dixon, Egerton and Gates).

The other phenomenon of detonative combustion is that which occurs generally in engines. By chemical reactions (chain reactions in the end-gas[23]) a critical stage is reached in which the end-gas ignites at one or more points. Combustion proceeds from these points at normal, subsonic speeds. This phenomenon also has its own definite time constants. In the end-gas there are three stages to be discerned when detonative combustion occurs: incubation, pre-reactions, combustion.

Among the factors upon which chemical detonation depends are:[24] fuel/air ratio, octane number, anti-knock agents, temperature and surface conditions of the combustion chamber walls, and the speed of the engine.

Poor mixtures may cause detonation; enriching the mixture may stop it. The lower the octane number, the earlier detonation will occur. Anti-knock agents may prevent or decrease detonation. The higher the temperature of the chamber walls, the earlier detonation will begin.

The speed also plays a role. If the engine runs very slowly, detonation may occur. This may be explained by considering that there is sufficient time so that stage three may be reached in the end-gas. (After the incubation period, which begins in the carburetor and intake manifold and the pre-reaction period, which also may begin in the intake manifold, the critical stage in the end-gas may be reached where peroxides are formed at such a rate that combustion occurs.) If, on the other hand, the engine runs very fast, temperatures in the combustion chamber increase in such a way that the walls may cause self-ignition of the end-gas before the primary flame front has proceeded through it.

It is possible that, after the stage of self-ignition in the end-gas is reached, physical detonation is also present. Further, experiments in bombs indicate that self-ignition may occur in the end-gas.[25]

Hence, it is concluded that the pre-stages of the two phenomena of physical and chemical detonation develop simultaneously. Each has its own history. Which critical point will be reached first depends upon the circumstances and upon what kind of detonation will occur primarily.

Appendix

Calculated Speeds of Sound and Combustion Speeds as Derived from Flame Pictures

Analysis of Fig. 3d

Fig. 3d has been analyzed and in Fig. 6a a drawing is shown giving a magnification of the boundary of the picture. Three phases are discerned. Phase 1 appears to be an induction period with a length of about 0.17 millisecond. In phase 2 the flame front is attaining an appreciable speed; the length of this phase is about 0.49 millisecond. Phase 3 suddenly evolves from phase 2; here the boundary of the flame picture has a tangential character. This third phase lasts until all of the fuel has been burned; its duration is about 0.20 second and it takes up about 85 per cent of the volume of the combustion chamber. The length of the combustion chamber, which is of uniform cross-section, being 10 cm., the combustion speed attained an average value of 500 meters per sec. during the third phase. This agrees with Weinhart's results.

The speed of sound existing under the conditions at the beginning of phase 3 has been calculated.

The speed of sound c for a gas of uniform temperature is

$$c = \sqrt{\kappa\, RTg/m}$$

in which

- κ = ratio of specific heats at constant pressure and constant volume, of the gas considered
- R = universal gas constant = 0.848 kilogram per degree mol.
- T = temperature of the gas
- g = acceleration of gravity = 9.813 meters per sec.^{2}
- m = molecular weight of gas considered

Applying this formula for the combustion considered for the end-gas, designated by the subscript e,

$$c_e = \sqrt{\frac{\kappa_e\, RT_e g}{m}}$$

For κ_e take 1.30 and for m_e, 29.0×10^{-3} kg. mol.

T_e is calculated from kindred relations as have been derived by Mache for the sphere.[26] T_e is a function of:

(1) the relative position of the flame front (here: 15 per cent of the total distance traveled by the flame front at the point considered),

(2) the ratio of the specific heats of the burned gases at constant pressure, respectively, constant volume (taken at 1.20),

(3) the temperature at the end of the compression stroke, or at the beginning of the combustion (calculated at 800° Kelvin for the present case),

(4) the heat content of the fresh gases (calculated at 726 cal. per gram mixture),

(5) the specific heat at constant pressure of the fresh gases (taken at 0.27 cal. per degree, gram mixture).

Lastly it appears that $T_e = 589°$ Kelvin at the beginning of phase 3 and therefore $c_e = 469$ meters per sec. Hence the average value of the combustion speed in phase 3 is larger than the speed of sound occurring under the conditions at the beginning of phase 3.

The flame picture shows further that the vibrations occurring have a frequency of 5400 Hz.

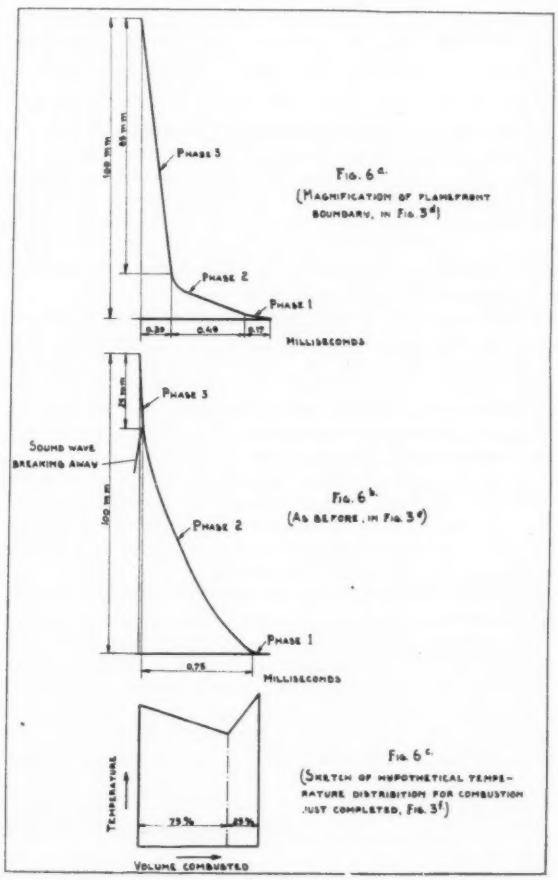


FIG. 6.

Analysis of Fig. 3e

In Fig. 6b a drawing of Fig. 3e is shown. One may find the phases as in Fig. 3d :

phase 1, duration not measurable;
phase 2, about 0.75 millisecond in duration;
phase 3, duration not measurable, but takes up about 25 per cent of the volume of the combustion chamber.

In this picture a pressure wave, proceeding downward from the critical point can be seen.

The speed of sound occurring at the beginning of phase 3, calculated as in the preceding analysis, is 520 meters per sec. The average speed of the pressure wave is 1150 meters per sec. That of the flame front cannot be measured.

Another interesting feature of this flame picture is that the character of the pressure waves corresponds with the temperature picture for the case of combustion given in Fig. 6c. This can be explained as follows.

For the normal combustion a distribution of temperature exists where the highest value is attained at the points where combustion first occurred. For the detonative combustion at supersonic speed, a distribution of temperature exists at the points where the highest value of combustion last occurred.[3] Hence a diagrammatic distribution for the temperature exists at the beginning of phase 3 of the flame picture similar to that given in Fig. 6c.

Assuming that the velocity of sound in a gas at a non-uniform temperature can be expressed by the formula used above, it follows that the highest velocities should occur near the end walls of the combustion chamber, where reflection occurs. The flame picture shows this. (Jouguet[10] calls attention to the fact that it still has to be shown that the formula for the velocity of sound for the case of a gas of uniform temperature may also be applied for the case where the sound wave is traveling in a gas at a non-uniform temperature.)

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Letter to the Editor

November 18, 1940

Dear Sir:

With regard to the reliability of John C. Silliman's Charts in the article *Elastic Stability Design Charts for Duraluminum Channels in Compression* published in the November, 1940, issue of the Journal of the Aeronautical Sciences (page 32), the following considerations may be of interest.

The shape of distortions of the cross section of the channel as shown in Fig. 4 and explained in the text suggests that the web and the flanges may be regarded as simply supported (or hinged) along their lines of intersection. This would be true only if the wave-pattern in the web and in the flanges were identical. Such is the case in the examples given in Timoshenko's *Theory of Elastic Stability* where a thin tube of square cross section (page 333) and an angle of equal legs (page 340) are considered. In the case of Silliman's figure, however, the length of a half-wave in the web should be equal to the width of the web, the length of a half-wave in the flange to the entire length of the channel, were the condition of simple support along the edges realized. This, however, leads to an inconsistency since such a pattern would involve a change of the original right angle between the tangents to the center line of the web and of the flange, causing moments at the edges A and B contrary to the assumption of simple supports. Therefore, the actual conditions at the edges correspond to a varying degree of elastic constraint, and the distorted shape of the cross section varies along the channel and generally differs from that given in Fig. 4. Here it may be cited that in Niles' *Experimental Study of Torsional Column Failure* (N.A.C.A. Technical Note No. 733) many test specimens developed two or three half-waves in the flanges and that there is no mention in the Note of wave formations in the web. All these discrepancies from the distorted shape underlying Silliman's charts evidently must cause a considerable change in the values of the coefficients in the formulas for buckling and for ultimate failure. The failing loads calculated according to Silliman's method should be regarded, therefore, as rough estimates only. As a matter of fact when carrying out similar calculations in their textbook *Aircraft Structures*, Niles and Newell suggest the use of a "form factor." The lowest value of this form factor in their example (Fig. 10:7) is 0.5. Of course, the likelihood of other types of instability, *e.g.*, Euler-buckling or twisting, should also be considered.

In Silliman's paper the explanation of the action of the different parts of the channel during the process of loading is not clear. If the writer's interpretation is correct, it is assumed that the flanges reach their critical load first, and the load on the entire channel is further increased after the flanges have buckled. In such a case, however, the flanges do not merely continue to carry their buckling load, but the stress in the fibers of the flanges near the "supported" edges increases while the load on the channel is increased. Simultaneously the stress in the fibers near the free edges of the flanges remains practically constant and the stress distribution over the width of the flange becomes non-uniform. The actual distribution can be replaced by a fictitious one corresponding to the concept of the effective width, and the load carrying capacity of the flange may be calculated by von Kármán's formula (Eq. 5 of Silliman's paper). In this formula, derived for the case when all four edges are simply supported, the constant coefficient should be multiplied by 0.355 according to Lundquist's suggestion (N.A.C.A. Technical Note No. 455). Fig. 1 of Silliman's paper and Fig. 2 of J. S. Dunning's Letter to the Editor* should be correspondingly revised.

N. J. Hoff
Polytechnic Institute of Brooklyn

* Journal of the Aeronautical Sciences, Vol. 8, No. 1, page 34, November, 1940.

An Experimental Verification of the Isotropy of Turbulence Produced by a Grid

D. C. MACPHAIL
Cambridge University

THE WORK of Dryden,[1] Simmons[2] and others in adapting the hot wire anemometer to the measurement of up-and-down stream turbulent velocity fluctuations is now well known. More recently Simmons, in an as yet unpublished report, has applied the inclined wire direction meter to the measurement of the turbulent velocities normal to the mean velocity. The method is a versatile one; and, in the present instance, is used to evaluate correlation coefficients $R_v = \overline{v_1 v_2}/\sqrt{\overline{v_1^2}\,\overline{v_2^2}}$ connecting simultaneous values of the transverse velocities at two fixed points in the turbulent region behind a grid.

In the experimental arrangement shown in Fig. 1, *a*, *b*, *c* and *d* represent heated platinum wires each about 0.15 cm. long and 0.00025 cm. diameter. These are supported in pairs on light wire prongs (Fig. 1a), and are placed in the turbulent stream of air with their apex pointing upstream. With the currents i_1 and i_2 adjusted by means of R_1 and R_3 so that the wires are heated to about 200°C., the resistance R_2 and R_4, and, if necessary, the orientations of the wire holders are adjusted until the Wheatstone bridges stay in mean balance (as registered by the galvanometers *G*) independently of small changes in the wind velocity *U*.

The turbulent "weaving" of the air in the plane *XOY*, say, of the wires *a* and *b* cools them differentially, and so alters their resistances differently. The resulting unbalance *e* of the Wheatstone bridge records, therefore, the stream's directional deviations v/U from the mean direction *OX*. The resistance-capacity coupled amplifier A_1 supplies to one coil of an electrodynamometer *D* a current proportional to instantaneous values of *e*.* On connection of the other coil of the electrodynamometer, the instrument deflects an amount

$$\delta_{12} = K_1 K_2 \overline{e_1 e_2}$$

K_1 and K_2 depending on the constants of the amplifiers and electrodynamometer. If, now, the electrodynamometer coils are connected in series, and supplied by A_1, the instrument moves so that

$$\begin{aligned} \delta_{11} &= K_1^2 \overline{e_1^2} \\ \delta_{22} &= K_2^2 \overline{e_2^2} \end{aligned} \qquad (1)$$

In a similar way

$$\overline{e_1 e_2} \Big/ \sqrt{\overline{e_1^2}\,\overline{e_2^2}} = \delta_{12}/\sqrt{\delta_{11}\delta_{22}} = R_0 \qquad (2)$$

When the components of air velocity past the center of wire *a* change from *U*,0,0 to $U + u_a, v_a, w_a$, the resulting change in temperature of this wire unbalances the bridge by an amount given approximately by

$$e_a = \alpha_a u_a + \beta_a v_a + \gamma_a w_a$$

if u_a, v_a, w_a are small. Turbulent velocities u_b, v_b, w_b at the wire *b* produce a further unbalance e_b, so that the unbalanced potential supplied to the amplifier is proportional to $e_1 = e_a + e_b$. Since the system is set to stay in balance independently of small changes in the wind velocity (for which $u_a = u_b$), $\alpha_a = -\alpha_b = \alpha_1$. γ_a and γ_b are found experimentally to be negligible. If the wires are nearly alike $\beta_a = \beta_b = \beta_1$. Then

$$e_1 = \alpha_1(u_a - u_b) + \beta_1(v_a + v_b)$$

For turbulence which is statistically uniform, and which transmits no mean shearing stresses,

$$\begin{aligned} \overline{u_a^2} &= \overline{u_b^2} = \overline{u^2} & \overline{v_a^2} &= \overline{v_b^2} = \overline{v^2} \\ \overline{u_a u_b} &= \overline{u^2} R_{u_\epsilon} & \overline{v_a v_b} &= \overline{v^2} R_{v_\epsilon} \\ \overline{u_a v_a} &= \overline{u_a v_b} = \overline{u_b v_a} = \overline{u_b v_b} = 0 \\ \overline{e_1^2} &= 2\alpha_1^2 \overline{u^2}\,(1 - R_{u_\epsilon}) + 2\beta_1^2 \overline{v^2}\,(1 + R_{v_\epsilon}) \end{aligned} \qquad (3)$$

$$\overline{e_1 e_2} = \alpha_1\alpha_2(\overline{u_a u_c} + \overline{u_b u_d} - \overline{u_a u_d} - \overline{u_b u_c}) + \beta_1\beta_2\,(\overline{v_a v_c} + \overline{v_a v_d} + \overline{v_b v_c} + \overline{v_b v_d}) \qquad (4)$$

The terms containing $\overline{uv}$ vanish as before.

For finding the tangential correlation R_z along a line at right angles to the stream, the wire centers are placed in a plane perpendicular to the direction of the mean velocity. The relative positions of the wires, as seen from upstream, are shown in Fig. 1b. If ϵ is small compared to *z*,

$$\begin{aligned} \overline{u_a u_c} &\approx \overline{u_b u_d} \approx \overline{u_a u_d} \approx \overline{u_b u_c} \approx R_{u_z} \\ \overline{v_a v_c} &\approx \overline{v_b v_d} \approx \overline{v_a v_d} \approx \overline{v_b v_c} \approx R_{v_z} \\ \overline{e_1 e_2} &\approx 4\beta_1\beta_2\,\overline{v^2}\,R_v \end{aligned} \qquad (5)$$

$$R_{v_z} = R_{0_z}\frac{\sqrt{\overline{e_1^2}\,\overline{e_2^2}}}{4\beta_1\beta_2\,\overline{v^2}} = R_{0_z}\sqrt{\left(\frac{1 + R_{v_\epsilon}}{2}\right)^2 + \frac{\overline{u^2}}{\overline{v^2}}\left(\frac{\alpha_1^2}{\beta_1^2} + \frac{\alpha_2^2}{\beta_2^2}\right)\left(\frac{1 - R_{u_\epsilon}}{2}\right)\left(\frac{1 + R_{v_\epsilon}}{2}\right) + \frac{\alpha_1^2\alpha_2^2}{\beta_1^2\beta_2^2}\left(\frac{\overline{u^2}}{\overline{v^2}}\right)^2\left(\frac{1 - R_{u_\epsilon}}{2}\right)^2}$$

In practice R_{u_ϵ} and R_{v_ϵ} are both in the neighborhood of

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* Subject to Dryden's correction.[2]

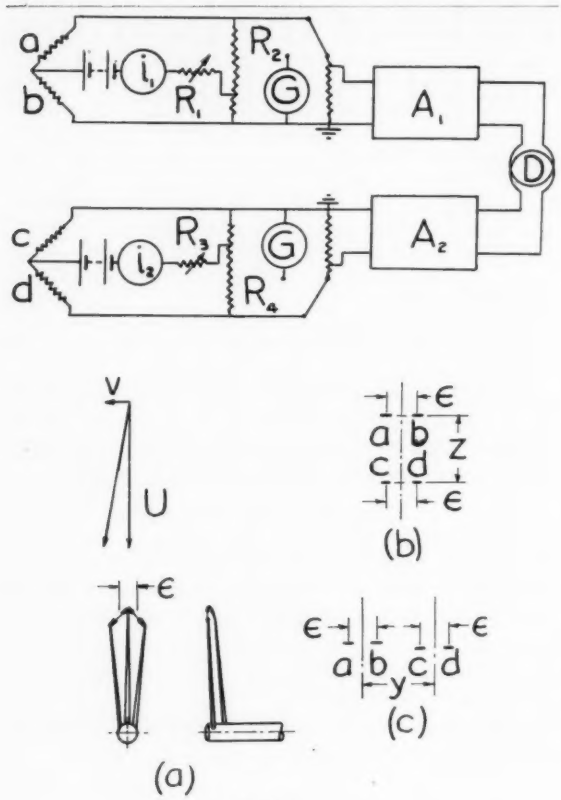

FIG. 1.

unity so that the second term is small, and the third is negligible.

$$R_{v_z} \approx R_{0_z}\left(\frac{1+R_{v_\epsilon}}{2}\right)\left[1+\frac{\overline{u^2}}{\overline{v^2}}\left(\frac{\alpha_1^2}{\beta_1^2}+\frac{\alpha_2^2}{\beta_2^2}\right)\left(\frac{1-R_{u_\epsilon}}{2}\right)\right]^{1/2}$$

$$\approx R_{0_z}\left(\frac{1+R_{v_\epsilon}}{2}\right)\left[1+\frac{1}{4}\frac{\overline{u^2}}{\overline{v^2}}\left(\frac{\alpha_1^2}{\beta_1^2}+\frac{\alpha_2^2}{\beta_2^2}\right)\left(1-R_{u_\epsilon}\right)\right] \quad (6)$$

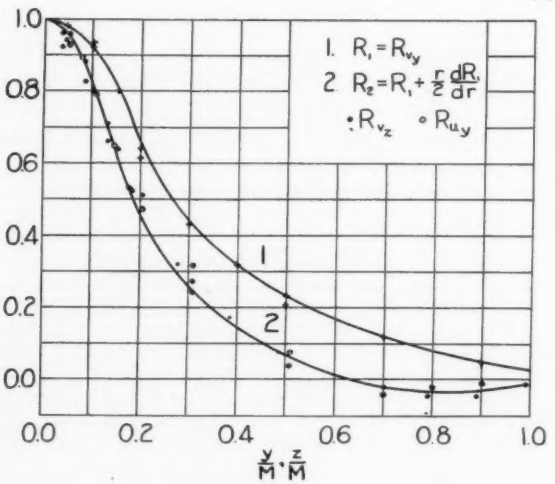

FIG. 2.

If the turbulence which is being measured is of such a large scale that

$$R_{u_\epsilon} = R_{v_\epsilon} = 1, \quad R_{v_z} = R_{0_z}$$

For finding the radial correlation R_1, the wire centers are placed in a line transverse to the stream, as in Fig. 1c. In that case

$$\overline{e_1 e_2} = \alpha_1\alpha_2\overline{u^2}(2R_{u_y} - R_{u_{y+\epsilon}} - R_{u_{y-\epsilon}}) + \beta_1\beta_2\overline{v^2}\,(2R_{v_y} + R_{v_{y+\epsilon}} + R_{v_{y-\epsilon}})$$

$$R_{v_y} \approx \frac{1}{2}\,(R_{v_{y+\epsilon}} + R_{v_{y-\epsilon}})$$

if ϵ is very much smaller than y.

$$\overline{e_1 e_2} \approx 4\beta_1\beta_2\,\overline{v^2}\,R_{v_y}$$

$$R_{v_y} = R_{0_z}\left(\frac{1+R_{v_\epsilon}}{2}\right)\left[1+\frac{1}{4}\left(\frac{\alpha_1^2}{\beta_1^2}+\frac{\alpha_2^2}{\beta_2^2}\right)\left(1-R_{u_\epsilon}\right)\right] \quad (7)$$

α and β can be found experimentally. α_1 is secured by measuring $\alpha_1 = \dfrac{\partial e_1}{\partial U_{e_1=0}}$ with one platinum wire replaced by an equal steady resistance. Measuring the bridge unbalance produced by rotation of the wire holder about $0Z$ in a steady stream of air gives the information to evaluate $\beta_1 = \dfrac{1}{2U}\dfrac{\partial e_1}{\partial \theta_{e_1=0}}$.

The quantities R_{v_y} and R_{v_z} found from Eqs. (6) and (7) correspond to von Kármán's[3] radial and tangential correlations R_1 and R_2, respectively. R_{u_y} which can be measured by means of two hot wires set at right angles to the stream and placed along a line perpendicular to the stream, can also be used for his tangential correlation R_2. He has shown that for isotropic and uniform turbulence

$$R_2 = R_1 + \frac{r}{2}\frac{dR_1}{dr} \quad (8)$$

For the present experiments a square mesh grid of round bars $^3/_8$ in. diameter spaced $M = 2$ in. apart was placed in the airstream of a new tunnel recently erected in the Cavendish Laboratory, Cambridge. In the absence of the grid, the stream was so steady that the measured value of $\sqrt{\overline{u^2}}/U$ was only 0.0007. The measurements were made 60 in. from the grid with $U =$ 30 ft./sec. $\sqrt{\overline{u^2}}/U = 0.018$, $\sqrt{\overline{v^2}}/U = 0.0185$. Taylor[4] has shown that von Kármán's relation (8) is satisfied when R_{u_x} is taken as R_1 and R_{u_y} or R_{u_z} is taken as R_2. The present observations show that the relation is also satisfied when R_{v_y} is taken as R_1, and either R_{u_y} or R_{v_z} is taken as R_2. Since, from the statistical point of view, the flow is certainly symmetrical with respect to y and z, von Kármán's relationship must be satisfied also when R_{w_z} is taken as R_1 and either R_{u_z} or R_{w_y} is taken as R_2. (See Fig. 2.)

The present position with regard to the verification of von Kármán's relationship between various correlations made in the air stream behind a square mesh grid of round bars may be summarized as follows. R_1 may be taken as R_{u_x}, R_{v_y} or R_{w_z}; and R_2 may be R_{u_y}, R_{u_z}, R_{v_z}, R_{v_x}, R_{w_x}, R_{w_y}. The relations verified by direct experiment are: 1 (R_{u_x}, R_{u_y}), 2 (R_{u_z}, R_{u_z}) by Taylor and Simmons; 3 (R_{v_y}, R_{u_y}), 4 (R_{v_y}, R_{v_z}) in the present instance. Owing to symmetry with respect to y and z, the following cases can be inferred: 5 (R_{w_z}, R_{u_z}), 6 (R_{w_z}, R_{w_y}). By combining these, von Kármán's relation must also be satisfied in the following cases: 7 (R_{u_x}, R_{v_z}), 8 (R_{u_x}, R_{w_y}), 9 (R_{v_y}, R_{u_z}), 10 (R_{v_y}, R_{w_y}), 11 (R_{w_z}, R_{u_y}), 12 (R_{w_z}, R_{v_z}).

Thus, in twelve out of the eighteen possible combinations of R_1 and R_2, von Kármán's relationship is satisfied. If any one of the six remaining relations were verified experimentally, the other five could be inferred from considerations of symmetry with respect to y and z. The difficulty in making such measurements accurately is that one pair of hot wires must be downstream from the other, and thus in its wake.

In conclusion the author should like to record his thanks to Prof. W. L. Bragg for the facilities of the Cavendish Laboratory, to Prof. G. I. Taylor for his guidance in the design and construction of the new tunnel, and to the Aeronautical Research Committee for their grant toward the work.

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Errata

Through typographical errors, the following two mathematical expressions were misprinted in the article on *Dimensionless Coefficients Applied to the Solution of Column Problems* by Kenneth G. Merriam which appeared in the September, 1940, issue of the Journal (page 478, first column).

1. l/r should have been made equal to

$$\beta\left(2\pi\sqrt{E/S}\right)$$

2. Euler's equation should have been corrected to read

$$P/A = \pi^2 E/(l/r)^2$$

A Hidden Safety Factor in the Design of Metal Wings

H. W. SIBERT

University of Cincinnati

Introduction

It has been pointed out recently that shear lag in metal wings causes a decrease in wing efficiency which may be appreciable for certain wings.* However, the Static Test Unit of the U.S. Army Air Corps has found that failing loads of metal wings for military planes generally range from 90 per cent to 110 per cent of the calculated design loads, despite the fact that it is customary for stress analysts to neglect entirely the effect of shear lag. This surprisingly close agreement between experimental and calculated design loads would seem to indicate that the bad effect of shear lag has been greatly exaggerated. However, shear lag could still cause a fairly large decrease in wing efficiency if there were an appreciable safety factor which had not been made use of in the calculated design load.

A Hidden Safety Factor

For the present it will be convenient to neglect shear lag, which is equivalent to assuming that each plane cross-section perpendicular to the neutral axis remains plane after bending. Hence, the strain at any point on such a cross-section is proportional to its distance from the neutral axis.

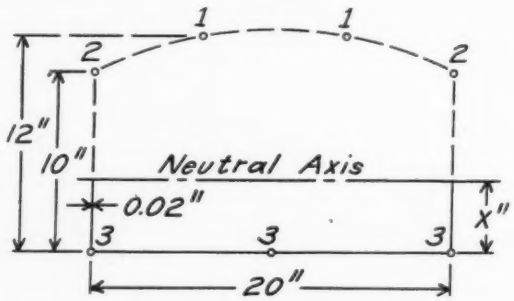

Fig. 1. Hypothetical beam cross-section.

Fig. 1 shows a hypothetical wing beam whose neutral axis is x inches above its lower surface when the upper portion of the beam is in compression. The skin is 0.02 inch thick throughout, the three lower concentrated areas are 0.1 sq.in. each, and the four upper concentrated areas (including the effective area of the adjacent skin) are each 0.11 sq.in. The ordinary beam theory, which is based on the assumption that the stress at any point of a cross-section is proportional to its distance from the neutral axis, requires the neutral axis to pass through the center of gravity of the effective area of the cross-section. Hence, according to this theory,

$$x = 3.97 \text{ in.}, \quad I = 34.05 \tag{1}$$

$$M = sI/c = s_1 \times 34.05/8.03 = 42.3s_1 \tag{2}$$

in which s_1 is the stress at point (1) in Fig. 1.

Fig. 2 shows the stress-strain curve in compression

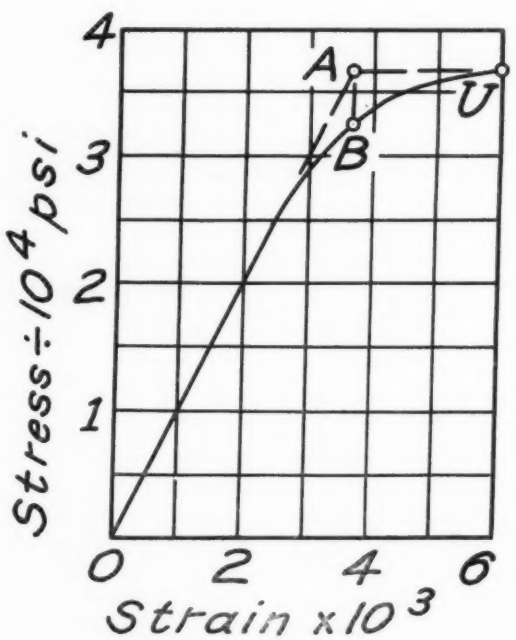

Fig. 2. Stress-strain curve of a longitudinal stiffener in compression.

for a 24ST bulb angle which was used in a military airplane. The ultimate compressive stress of 36,700 lbs. per sq.in. occurred at a strain of 0.006. If this bulb angle were used at points (1) and (2) in Fig. 1, the maximum allowable moment according to the ordinary beam theory would be (Eq. (2))

$$M_m = 42.3 \times 36{,}700 = 155{,}400 \text{ in.-lb.} \tag{3}$$

Received July 15, 1940.

* Sibert, H. W., *Effect of Shear Lag upon Wing Strength*, Journal of the Aeronautical Sciences, Vol. 6, No. 10, Aug., 1939.

Let E be the modulus of elasticity as determined from the straight-line portion of the stress-strain curve, and let subscripts c and t stand for compression and tension, respectively. For the bulb angle shown in Fig. 2, $E_c = E_t = 10{,}000{,}000$ lbs. per sq.in., while the proportional limit in tension was over 40,000 lbs. per sq.in. Moreover, the neutral axis of the cross-section in Fig. 1 was nearer to the lower than it was to the upper surface of the beam. Hence, when the ultimate compressive stress of 36,700 lbs. per sq.in. is not exceeded at the extreme area in compression, the stress at any point on the tension side of the cross-section will be below the proportional limit in tension and will be equal to 10,000,000 λ, where λ is the strain at that point. This simple relation does not hold for all parts of the cross-section above the neutral axis because the stress-strain curve in compression (Fig. 2) is not a straight line for stresses as high as 36,700 lbs. per sq.in. Hence, the fundamental assumption of the ordinary beam theory is violated, and the true neutral axis cannot be at the center of gravity of the effective area of the cross-section.

The true neutral axis must be so located that $F_c = F_t$, where F_c and F_t are, respectively, the resultant tensile and compressive force on the cross-section. The true neutral axis can be found by a process of trial and error by assuming two values of x (Fig. 1) and calculating the corresponding ratios of F_c/F_t and then interpolating to find the x for which $F_c/F_t = 1$. This procedure applied to Fig. 1 gave $x = 3.08$ inches, the accuracy of which will be tested below.

Let λ_2 and λ_3 be the strain at points (2) and (3), respectively, when the stress at point (1) is 36,700 lbs. per sq.in., and let s_2 and s_3 be the corresponding stresses. Recall that the strain at any point is proportional to its distance from the neutral axis when there is no shear lag. Hence, with $x = 3.08$ inches and the strain at point (1) equal to 0.006 (Fig. 2),

$\lambda_2 = 0.006 \times 6.92/8.92 = 0.00466$
$\lambda_3 = 0.006 \times 3.08/8.92 = 0.002072$
$s_2 = 35{,}200$ lbs. per sq.in. (Fig. 2)
$s_3 = 0.002072 \times 10{,}000{,}000 = 20{,}720$ lbs. per sq.in.
$F_1 = 2 \times 0.11 \times 36{,}700 = 8074$ lbs.
$F_2 = 2 \times 0.11 \times 35{,}200 = 7744$ lbs.
$F_3 = (3 \times 0.1 + 20 \times 0.02)\ 20{,}720 = 14{,}504$ lbs.
F_4 (vertical webs) $= 2 \times 0.02 \times 3.08 \times 20{,}720/2 = 1276$ lbs.
$F_c = 8074 + 7744 = 15{,}818$ lbs.
$F_t = 14{,}504 + 1276 = 15{,}780$ lbs.

Since F_c/F_t is so near to unity, $x = 3.08$ inches must be very close to the correct value of x. The true maximum moment which can be carried by this cross-section equals the sum of the moments of forces F_1, F_2, F_3, and F_4. Since F_4, the resultant force on the vertical webs, acts at a distance of $^2/_3 \times 3.08$ inches from the neutral axis,

$$M_m = 8074 \times 8.92 + 7744 \times 6.92 + 14{,}504 \times 3.08 + 1276 \times {}^2/_3 \times 3.08 = 172{,}900 \text{ in.-lb.} \quad (4)$$

From Eqs. (3) and (4) it is evident that the application of the ordinary beam theory to Fig. 1 produces a hidden safety factor equal to $(172{,}900 - 155{,}400)/155{,}400 = 11$ per cent.

This safety factor, which is due to the curvature of the stress-strain curve in compression, will have different magnitudes for different beam cross-sections. However, an approximate value of its magnitude for any cross-section can be obtained directly from the stress-strain curve in compression in the following manner. When the ordinary beam theory gave for the maximum moment a stress of 36,700 lbs. per sq.in. for the outermost area in compression, it merely meant that the stress would have that value if the stress-strain curve in compression were straight as far as 36,700 lbs per sq.in. This is equivalent to saying that the strain for that area is $36{,}700/E_c = 36{,}700/10{,}000{,}000 = 0.00367$. From Fig. 2 a strain of 0.00367 corresponds to a stress of 32,500 lbs. per sq.in. Hence, the true stress at this outermost area in compression is actually 32,500 lbs. per sq.in. instead of 36,700 lbs. per sq.in. which gives a safety factor of $(36{,}700 - 32{,}500)/36{,}700 = 12$ per cent.

The dashed-line construction shown in Fig. 2 is equivalent to the argument given above for finding the actual stress of 32,500 lbs. per sq.in. In this construction U is the ultimate compressive stress, UA is a horizontal line from U to the extension of the straight line portion of the stress-strain curve, AB is a vertical line and the stress at B is 32,500 lbs. per sq.in. Actually, the stress at B in Fig. 2 is only an approximation to the true stress at the outermost area in compression because an average modulus of elasticity for the whole cross-section should be used instead of E_c. Unfortunately, the value of this average modulus of elasticity is a function of the true location of the neutral axis and the area distribution for the cross-section in question.

Effect of Shear Lag

Shear lag produces warping of a cross-section, which in turn causes a transfer of load from intermediate stringers to the stringers adjacent to the wing beams. On the other hand, the hidden safety factor previously exhibited in this paper depends upon the curvature of the stress-strain curve in compression and would be present in a warped cross-section as well as in one which remained plane after bending. Thus, a more exact analysis for a wing beam should take into account both shear lag and the safety factor due to curvature of the stress-strain curve. However, as long as designers neglect the bad effect of shear lag, it might be wise for them to neglect also the good effect of this hidden safety factor.

Institute Notes

Wright Brothers Lecture

Tuesday, December 17, 1940, at 8:30 p.m.
The Pupin Physics Laboratories, Columbia University, Broadway and 120th Street, New York City

"Recent Fog Investigations," by Dr. Sverre Petterssen, Professor of Meteorology, Massachusetts Institute of Technology

Honorary Chairman:
Griffith Brewer, President, Royal Aeronautical Society of Great Britain

Discussion by:
F. W. Reichelderfer, Chief, U.S. Weather Bureau—Chairman
H. G. Houghton, Asst. Prof. of Meteorology, Massachusetts Institute of Technology
E. J. Minser, Chief Meteorologist, TWA, Inc.
C.-G. Rossby, Asst. Chief for Scientific Services, U.S. Weather Bureau
A. F. Spilhaus, Assoc. Prof. of Meteorology, New York University

Dinner in Honor of the Wright Brothers Lecturer

Tuesday, December 17, 1940 at 6:30 p.m.
Men's Faculty Club of Columbia University, Morningside Drive and 117th Street, New York City
(Informal. Tickets at $2.00 each should be ordered in advance from the Institute.)
Toastmaster: Major J. H. Doolittle, President, Institute of the Aeronautical Sciences
"The Beginnings of the American Aircraft Industry—the First Wright Company," by Grover Loening and Frank H. Russell

Ninth Annual Meeting Program

Honors Night Dinner
Biltmore Hotel, New York City
Tuesday, January 28th, 1941, at 7:00 p.m.

Guest Speaker:
Griffith Brewer, President, Royal Aeronautical Society of Great Britain

Technical Sessions
Pupin Physics Laboratories, Columbia University
New York City

Wednesday, January 29th, 1941
9:15 a.m. to 12:30 p.m.:
Rotating-Wing Aircraft, Richard H. Prewitt, Chairman
Radio and Instruments, Charles H. Colvin, Chairman
2:00 p.m. to 5:00 p.m.:
Rotating-Wing Aircraft, Richard H. Prewitt, Chairman
Physiological Problems, Arnold D. Tuttle, Chairman
5:00 p.m.
Annual Business Meeting of the Members of the Institute

Thursday, January 30th, 1941
9:15 a.m. to 12:30 p.m.:
Power Plants, C. Fayette Taylor, Chairman
Organic and Synthetic Materials, William C. Geer, Chairman
2:00 p.m. to 5:00 p.m.:
Structures, John E. Younger, Chairman
Air Transport, J. Parker Van Zandt, Chairman

Friday, January 31st, 1941
9:15 a.m. to 12:30 p.m.:
Airplane Design, William H. Miller, Chairman
Meteorology, Athelstan F. Spilhaus, Chairman
2:00 p.m. to 5:00 p.m.:
Aerodynamics, W. Bailey Oswald, Chairman

(A program of the papers to be presented is being prepared and will be mailed to members of the Institute shortly.)

R. Ae. S. President to Speak at Honors Night Dinner

Griffith Brewer, President of the Royal Aeronautical Society of Great Britain, will be the principal speaker at the Institute's Honors Night Dinner in New York on January 28th. The Institute is most fortunate in having the distinguished president of the oldest aeronautical society in the world as guest of honor and speaker on this occasion.

Mr. Brewer's notable career in aviation began in 1891 with his activities as a balloonist, which included participation in the Gordon Bennett and other balloon races. When he rode as a passenger with Wilbur Wright at Le Mans, France, in 1908, he became the first Englishman to fly in a heavier-than-air machine. He took flying lessons at the Wright Brothers school in Dayton and received his American airplane pilot's certificate in 1914. He delivered the Wilbur Wright Memorial Lecture in 1916. Mr. Brewer has participated since 1903 in the work of the Royal Aeronautical Society, of which he is an Honorary Fellow. He is well known in American aviation circles, having visited this country many times and flown over the principal airlines of the United States and Latin American countries.

Dr. John Jeffries Award

The Council of the Institute at its meeting on November 8th, formally established the Dr. John Jeffries Award "for outstanding contributions to the advancement of aeronautics through medical research."

This award honors the memory of Dr. John Jeffries, the Boston physician, who, in 1785, accompanied the French balloonist Blanchard on the first aerial voyage across the English Channel. Dr. Jeffries was one of the first Americans to take a practical interest in aeronautics, not only in giving financial aid to early experimenters, but in devising instruments and making the first scientific observations from a balloon in flight. Since Jeffries was a practicing Doctor of Medicine, an award in his name to encourage research in the fields of physiology and medicine applicable to aviation was deemed by the Council to be a particularly fitting memorial to be sponsored by the Institute of the Aeronautical Sciences.

The following have been invited to serve as a Committee of Award:

The Director of Research of the National Advisory Committee for Aeronautics
The President of the National Aeronautic Association
The President of the Air Transport Association of America
The President of the Aero Medical Association
The President of the Aeronautical Archives
The President of the Institute of the Aeronautical Sciences

The Committee will choose the first recipient of this annual award to receive a certificate with citation at the next Honors Night Dinner of the Institute on January 28, 1941.

The Losey Award for Aerology

Also established at the same Council meeting was The Losey Award for Aerology in honor of the late Captain Robert M. Losey, a member of the Institute, who was killed at Dombas, Norway, April 21, 1940, at the age of 31. He was the first American official to fall a victim in the present European war.

At the time of his death Captain Losey was on duty as an observer for the United States Government in his capacity as Assistant Military Attache to Norway and Sweden. A graduate of the U.S. Military Academy and the California Institute of Technology, he had been a pilot and an aerological officer in the Army Air Corps since 1931. Prior to his last assignment to duty overseas, he was one of the chief meteorological advisers attached to the Office of the Chief of the Air Corps.

The Losey Award will be given annually "for outstanding contributions to the science of meterology as applied to aeronautics." The first certificate and citation for this award will also be presented at the Honors Night Dinner in January.

Those invited by the Council to compose the Committee for The Losey Award for Aerology are:

The Chief of the United States Weather Bureau
The Chairman of the Executive Council of California Institute of Technology
The President of Massachusetts Institute of Technology
The President of the American Meterological Society
The President of the Aeronautical Archives
The President of the Institute of the Aeronautical Sciences

Kollsman Library in Operation Three Months

Since it commenced operation the first of September, The Paul Kollsman Library has made over 400 loans of books to members. More than 700 persons have registered with the Library for the purpose of borrowing aeronautical books by mail which are loaned at no cost other than the few cents required for return postage on each book.

There are now close to 2800 separate titles in the Library. The list published in the first issue of the "Aeronautical Reader's Guide," which was sent to subscribers and all Institute members in September, gives a classified catalogue of those of the Library's books which were published since 1930. It will be supplemented by the list of new accessions in the second number of the "Guide," which is being published early in December. All books reviewed in the "Aeronautical Review Section" of the Journal are also available on loan. In fact, new aeronautical books are added to the Library as soon as they are issued by their publishers so that requests for new books can be filled even before the reviews of them have appeared.

Robert Dexter, Director of The Paul Kollsman Library, has pointed out that practically any aeronautical or technical book, old or new, with the exception of very rare and out of print volumes, can be obtained on request whether it has been listed in the "Aeronautical Reader's Guide" or not. The resources of The Kollsman Library in respect to general technical books are augmented through the reciprocal borrowing arrangements it has with the Engineering Societies Library of 142,000 volumes. Many members contemplating the purchase of aeronautical books have found the facilities of The Kollsman Library a great convenience. They can borrow the library copy of a book for seven days in order to inspect it; then if they wish to buy a copy it can be ordered directly from The Kollsman Library. Although the Library does not lend or take orders for periodicals or government reports, it is able to help those who cannot obtain copies from publishers or dealers by having photostats of articles and reports made at low cost.

The recent gift of $50,000 establishing The Paul Kollsman Library and its publications has resulted in one of the most worth while additions yet made to the services rendered by the Institute. Favorable comment and expressions of appreciation have come in from all sides concerning the book lending service, the useful catalogue provided by the "Aeronautical Reader's Guide," and the important function served by the monthly "Aeronautical Review" which keeps readers up-to-date on all new literature and developments in aeronautics and saves much valuable time for those who are busy in the present-day expansion of aviation activities.

Members of the Institute who have not already done so are invited to apply for membership in The Kollsman Library and make use of its borrowing privileges. Application blank and book order cards will be sent promptly on request. Nonmembers of the Institute who furnish adequate references or a book deposit fee can also make use of the lending library.

Bibliography of Aeronautics

The Bibliography of Aeronautics, prepared by the Works Projects Administration under the direction of the Institute, has been completed. The fifty volumes have been distributed to libraries, universities and government departments. No more copies of the edition are available and therefore sets cannot be sent to others. The Institute will be glad to inform anyone where a set may be consulted.

There are 5,671 pages in the fifty volumes. They contain 77,519 references. The author index contains 23,813 names of authors. It is now being brought up to date by supplementary volumes which will be sent to complete the sets that were first distributed.

Gifts to the Institute

Many items in the steadily growing collections being obtained by the Aeronautical Archives need exhibition cases for their proper display. For this purpose the Bendix Aviation Corporation generously presented to the Institute one of the attractive glass-topped stands which they used in their exhibits at the New York World's Fair. The medallions and medals which were presented to the Institute by A. P. Loening and Lester D. Gardner have been placed in this case. To these has been added the remarkably fine collection of Mrs. Bella C. Landauer, which contains many of the medallions commemorating famous events in aeronautical history. The entire collection is now on exhibition at the Institute.

Until the closing of the New York World's Fair in October there had been on exhibition in the Italian Pavilion a representative collection of models of Italian airplanes. Through the courtesy of Colonel Giuseppe Gaeta, Air Attache of the Italian Embassy, eighteen of these models have been placed in the custody of the Institute on indefinite loan. They make an interesting addition to the collection of models exhibited in the Aeronautical Archives.

Personnel Opportunities

The Personnel Bureau serves individual members, as well as organizations seeking to employ aeronautical specialists. Any member or organization may have requirements listed without charge.

Wanted

A Midwestern college has an opening for an instructor in aeronautical engineering to teach classes in structural analysis and design and also to develop a structural research program. Applicants should have the equivalent of a master's degree in engineering, as well as several years' experience in structural analysis in the aircraft industry. Salary will be commensurate with qualifications. Address reply to Box 114, Institute of the Aeronautical Sciences.

Wanted

A large southwestern college is expanding its aeronautical facilities and will be in need of staff members to teach subjects in the aeronautical engineering department. Applicants are required to have a degree in aeronautical engineering as well as practical experience in the aeronautical field. Preference will be given to those holding advanced degrees. Excellent opportunity is provided for development and advancement in the field. Ample opportunities and facilities will be provided for research, development and consultation. The college owns a large airport which is now being developed and participates in both primary and secondary phases of C.P.T. Training. There will be some increases in the staff shortly after the first of the year. Consideration will be given to those applicants who desire to join the staff as of September 1, 1941. In applying please give a brief sketch of personal qualifications, education and experience. Address reply to Box 115, Institute of the Aeronautical Sciences.

Available

Aeronautical engineer, familiar with Air Corps design and contract procedure, desires an opportunity to make new connection. Continuously employed for approximately 14 years as engineer in connection with production statistics and procurement planning relating to the manufacture of aviation products including airplanes, engines and accessories, and concurrently as a special lecturer for 5 years in an aeronautical school of a large university. Address reply to Box 116, Institute of the Aeronautical Sciences.

Student Branches

Alabama Polytechnic Institute. At the first meeting of the school year, held on October 28th, the following officers were elected: Prof. Robert G. Pitts, Honorary Chairman; William O. Farrior, Chairman; Lawrence E. Heyduck, Vice-Chairman; and Edwin C. Allen, Secretary-Treasurer.

University of Alabama. "A Method of Decreasing Costs and Increasing Speed of Production of Planes," the Student Branch Lecture, by C. F. Nagel, Jr., was presented by Samuel Hayden at a meeting held on October 28th.

Casey Jones School of Aeronautics. A regular business meeting was held on October 24th attended by about 75 members.

Massachusetts Institute of Technology. The first meeting of the school year was held on October 28th at which time the Student Branch Lecture "Economic Factors in the Evolution of Air Transport," by E. P. Warner, was presented by Ben Follett, General Manager of Wiggins Airways.

University of Michigan. Officers of the Student Branch are: Prof. M. J. Thompson, Honorary Chairman; Leslie J. Trigg, Chairman; (Vice-Chairman to be elected); Leon R. Wosika, Treasurer; and Edward A. King, Secretary.

University of Notre Dame. Fifty members attended the first meeting at which time officers were elected. They are: Prof. F. N. M. Brown, Honorary Chairman; Mario Pottetti, Chairman; John Hoelscher, Vice-Chairman; and Raymond Schlesier, Secretary-Treasurer.

Oregon State College. At the first meeting of the school year, held on October 10th, Walt Walling presented a paper on "Trends in Design and Economics of Transport Planes." Letters from former students Oliver Glenn, Cliff Parmellee, Louis Kneer and William McKee (all members of last year's graduating class) were read. On October 22nd, Prof. Benjamin F. Ruffner, Honorary Chairman, Richard Smith, Calvert Mattern, George Hemingway, Alex Weaver, Floyd Loomis and Walt Walling attended the Annual Banquet and National Officers Meeting of the Society of Automotive Engineers at Portland, Oregon. On November 7th, at a meeting presided by Chairman Richard Smith, Robert Person gave a lecture on photoelasticity.

Stanford University. The first meeting was held on October 22nd at which time the Institute film "Streamline Visualization" was shown. In addition to regular Student Members, the meeting was attended by a group of engineers from the Ames Laboratory staff of the N.A.C.A. Later, a business meeting was held. Officers elected are: Prof. Elliott G. Reid, Honorary Chairman; Howard E. Roberts, Chairman; Richard Williams, Vice-Chairman; and Robert W. Hovey, Secretary-Treasurer.

Tri-State College. On September 30th, officers were elected as follows: Prof. M. E. Collins, Honorary Chairman; Emil Schuld, Chairman; LeRoy Krouse, Vice-Chairman; and Delbert J. Forward, Secretary-Treasurer. Subsequent meetings were held on the 14th, 21st and 28th of October. At a meeting held on November 4th, the Student Branch Lecture by C. F. Nagel, Jr., on "A Method for Decreasing Costs and Increasing Speed of Production of Planes" was presented by Art Baldwin.

Virginia Polytechnic Institute. The Branch Lecture on "A Method of Decreasing Costs and Increasing Speed of Production of Planes" by C. F. Nagel, Jr., was presented by Meyer B. Salomonsky at a meeting held on October 29th. Officers for 1940–41 are: Capt. John H. Wright, Honorary Chairman; Bruce H. Pauly, Chairman; Meyer B. Salomonsky, Vice-Chairman; and John W. Martin, Secretary-Treasurer.

Sections

Los Angeles. At a dinner meeting held on October 7th, Warren T. Dickinson presented a paper on "Flight Testing for Carburetor Preheat." A discussion followed; those participating included Messrs. Morse of the General Electric Company, Thoren of the Lockheed Aircraft Corporation, Klemperer of the Douglas Aircraft Company, Johnson, Goodman and Nutt of the Wright Aeronautical Corporation, Gosselin and Cutting of Pratt & Whitney Aircraft, and Ashley of the C.A.A.

Changes in Membership

The following changes in the membership of the Institute have occurred since the publication of the previous issue of the Journal.

Elected to MEMBER Grade

Arslan, Albert Edward, M.S.; M.I.Ae.S.; Project Stress Engineer, Vultee Aircraft, Inc.

Beebe, Murray Charles, Jr., S.B. in M.E.; M.I.Ae.S.; Experimental Engineer, Hamilton Standard Propellers Div., United Aircraft Corp.

Beeuwkes, Reinier, Jr., D.Sc.; M.I.Ae.S.; Instructor, Case School of Applied Science.

Berkow, Murray, B.S. in M.E.; M.I.Ae.S.; Chief Engineer, Central Aircraft Corp.

Blaisdell, Allen H., B.S. in M.E.; M.I.Ae.S.; Prof., Aero. Engineering, Carnegie Inst. of Technology.

Collins, Millford Edward, B.S. in Ae.E.; M.I.Ae.S.; Prof., Aero. Engineering, Tri-State College.

Der Yuan, Frank, B.S. in Ae.E.; M.I.Ae.S.; Technical Asst., Intercontinent Corp.

Deyarmond, Albert Bonnell, B.S. in Ae.E.; M.I.Ae.S.; Chief, Stress Dept., Vultee Aircraft, Inc.

DuBois, Ralph Nicholas, B.S. in M.E.; M.I.Ae.S.; Exec. Engineer, Aircraft Engines, Packard Motor Car Co. (See W.W. in Eng.)

Graham, Ernest Washburn, M.S. in M.E.; M.I.Ae.S.; Aero. Engineer, Douglas Aircraft Co.

Hurty, Walter Carl, B.S. in Ae.E.; M.I.Ae.S.; Structures Engineer, Vega Airplane Co.

Johnston, Robert Bethel, M.S. in M.E.; M.I.Ae.S.; Engineer Ryan Aeronautical Co.

Klose, Alfred Julius, B.S. in M.E.; M.IAe.S.; Engineer in Charge of Preliminary Design, Vultee Aircraft, Inc.

Lightfoot, Ralph Butterworth, B.S. in M.E.; M.I.Ae.S.; Aero. Engineer, Vought-Sikorsky Aircraft, United Aircraft Corp.

Mangurian, George Nishan, M.S. in C.E.; M.I.Ae .S.; Project Stress Engineer, Glenn L. Martin Co.

Simms, Manuel Sterling, B.Ae.E.; M.I.Ae.S.; Stress Analyst, Northrop Aircraft, Inc.

Smith, Dean Cullen, M.I.Ae.S.; Director of Sales, St. Louis Airplane Div., Curtiss-Wright Corp.

Strunk, Kenith Goodrich, B.S. in Ae.E.; M.I.Ae.S.; Chief Engineer, Breeze Corps., Inc.

Varela-Cid, Arthur, Dr. Eng.; M.I.Ae.S.; Founder, Instituto para Estudos Aeronauticos; Research, Superior Technical Inst. and Faculty of Sciences, Univ. of Lisbon, Portugal.

Vollmer, Richard Frederick, B.S. in Ae.E.; M.I.Ae.S.; Leadman, Brewster Aeronautical Corp.

Wolf, Walter A., M.I.Ae.S.; Engine Designer, Wright Aeronautical Corp.

Worley, George Francis, Ae.E.; M.I.Ae.S.; Aero. Engineer, Douglas Aircraft Co.

Elected To Industrial Member Grade

Breech, Ernest Robert, M.I.Ae.S.; Chrmn. Bd. Directors, North American Aviation, Inc.; Mem. Bd. Directors, Bendix Aviation Corp.; Vice-Pres., General Motors Corp. (See W.W. in A.)

Francis, Parker Browne, A.B.; M.I.Ae.S.; Pres., Puritan Compressed Gas Corp.

Hagar, Hamilton, A.B.; M.I.Ae.S.; Aviation Research, Industry and Security Survey Corp.

Johnson, Ernest Eldon, B.S. in E.E.; M.I.Ae.S.; In charge Aeronautic Equipment Div., Aero. & Marine Eng. Dept., General Electric Co.

Neilson, Preston Matt, B.S.; LL.B.; M.I.Ae.S.; Pres., Central Aircraft Corp. (See W.W. in N.Y.)

Elected To Technical Member Grade

Arnold, Lee, M.S. in E.; Vibration Engineer, Glenn L. Martin Co.

AuWerter, Jay Pearce, M.S.; Asst. Editor, Aviation Magazine.

Burrier, Horace Eugene, B.S. in M.E.; Engineer, North American Aviation, Inc.

Dvorak, Harry W., Aero. Engineer, Consolidated Aircraft Corp.

Flynn, Patrick Thomas, B.Ae.E.; Layout Draftsman, Lockheed Aircraft Corp.

Forney, Kenneth Adrian, M.S. in Ae.E.; Jr. Aero. Engineer, Aero. Engine Lab., Naval Aircraft Factory.

Go, Chong-Hu, B.S. in M.E.; Guggenheim School of Aeronautics, Calif. Inst. of Technology.

Goring, Gilman Rogers, B.M.E.; Engineer, Propeller Div., Canadian Car & Foundry Co. Canada.

Gough, William Vernon, Jr., B.E. in M.E.; Naval Aviator, U.S. Naval Reserve.

Irving, David Edwin, B.S. in Ae.E.; Chief of Structures, Aircraft Div., Edward G. Budd Mfg. Co.

Jones, Lester C., Engineering Draftsman, Lockheed Aircraft Corp.

Kujawa, Leo Joseph, B.Ae.E.; Exec. Field Engineer, Parker Appliance Co.

Pepper, Edward, B.S. in M.E.; Jr. Aero. Engineer, N.A.C.A.

Prentice, Bruce Robinson, B.S. in E.E.; Engineer, Aero. & Marine Eng. Dept., General Electric Co.

Smith, James Norman, B.S. in E.E.; Engineer, Process Engineering Dept., Vultee Aircraft, Inc.

Transferred to MEMBER Grade

J. Robert Fischel, Research Engineer, Lockheed Aircraft Corp.; Nicholas J. Hoff, Instructor, Aero. Engineering, Polytechnic Institute of Brooklyn; Wilbur C. Nelson, Asst. Prof., Aero. Engineering, Iowa State College.

The Technical Information Service
of the
Institute of the Aeronautical Sciences

This service has experienced personnel under the supervision of trained aeronautical engineers to compile any information desired. The services range from listing specialized reference books to the preparation of exhaustive bibliographies, digesting of reports and general surveys of any aeronautical subject.

Some of the available services are:

Bibliographies on any aeronautical subject.

Reports on any aeronautical subject.

Digests of aeronautical books, papers, periodicals and references.

Translations in all languages.

Engineering investigations of special aeronautical subjects.

Biographies of individuals engaged in aeronautics.

Photostats of any aeronautical or general engineering material.

Microfilms made on special order.

Photographs made from the Institute's photographic collection.

Drawings and tracings made.

In addition to the services mentioned any commission which comes within the scope of the Service will be accepted.

Research work is charged at the usual library fee of $2.00 per hour. Special arrangements may be made for work requiring several weeks or months.

Translators are available for accurate transcriptions of all foreign language data. Translations are carefully edited by trained engineers at the standard rate of 1¢ per word. Minimum charge, $2.00.

Reproductions of any material in the Aeronautical Archives of the Institute may be ordered at standard photostat rates.

Aeronautical Reviews

These brief reviews of recent articles on aviation subjects are published by the Army Air Corps for the information of its officers, and are printed here each month by permission of the Chief of the Air Corps

Aerodynamics

Design for Research. C. L. Johnson. All of the sections through the air passages (with the exception of the propeller station) are rectangular instead of circular, in the new wind tunnel of the Lockheed Aircraft Corporation. Full-size tunnel will be 170 ft. long and 70 ft. wide, and the air passage will contract from 30 × 20 ft. to 12 × 8 ft. at the test section. It will be built completely of reinforced concrete having a very smooth surface on the inside. A 20 ft. diameter six-bladed propeller will be driven by a 1500 hp. electric motor. Airspeed at the test section will be 260 m.p.h. but methods of increasing the test speed to much higher values after the tunnel is in operation are being studied. Corner guide vanes are provided with water cooling.

Corner vane shape, propeller design, contraction to the test section and all the various design factors were developed in a 1/8 scale model tunnel which will later be used for testing miscellaneous instruments and parts. Above the large wind tunnel are shop facilities for building models, drafting rooms, computing rooms, offices and a movie projection room to show pictures taken of airflow around the model. Photographic development laboratory is located in the basement so that test data can be made available for reading a few minutes after the test is run. New tunnel and its development, and the aerodynamic laboratory are described. *Western Flying*, September, 1940, pages 16–17, 4 illus.

Visible Vortices. Evidence from photographs and statements regarding the white sky trails, which are made by aircraft at high altitudes and are frequently seen over England, is summarized and analyzed. There are two phenomena: the wing tip trail, and the trail formed of air which has passed through the propeller and is therefore of helical shape. A flat trail which corresponded to the wing span was left by a Spitfire. It is pointed out that the more nearly the wing loading corresponds to an elliptical curve, the less does the vortex tend to be concentrated at the wing tip, and the more it approaches to an evenly distributed vortex sheet across the span. If it were only the condensation of exhaust gas which caused the trail, the trail would be continuous, but all agree that breaks occur. Formation of slipstream trails should not depend on speed of the airplane. Other examples of unusual phenomena are described. *Flight*, September 5, 1940, pages 186d–186e, 2 illus.

Air Forces on Radial Air-Cooled Engine Cowling (as Determined from Pressure Distribution Tests). R. R. Higginbotham, Republic Aviation Corp. Paper previously abstracted from preprint. (See *Technical Data Digest*, April 1st issue, page 1, for abstract.) *S.A.E. Jour. (Trans.)*, September, 1940, pages 370–396, 25 illus., 4 tables, 14 equations.

Northrop Wind Tunnel. E. Wilson. Largest section is 35½ ft. wide and 22½ ft. high with the average size 22½ ft. in diameter, narrowing to a 12 ft. throat section in which the model is mounted. Working section is housed in a two-story laboratory 25 × 40 ft. and 20 ft. high. Tunnel is of the same size as that at Cal. Tech. and was designed by the Northrop Engineering Department under the direction of T. von Kármán and W. Sears. It is of the return type and is constructed of electric-welded sheet steel with reinforcing and support members of structural shapes, mounted in concrete. Description. *Aviation*, October, 1940, pages 46–47, 3 illus.

Aircraft Design

Possibilities of Large Flying Boats for National Defense. H. Alfaro. Characteristics of a large flying boat, the largest that the present state of knowledge makes it feasible to construct, are presented, and its possible military services are considered. Present war has not definitely established whether airplanes are sufficient for coastal defense or are to be preferred to battleships, but there is a tendency toward aircraft. Ninety-four flying boats of this type could be constructed for the cost of one battleship. Load-carrying capacities of both are compared, and strategic value of the flying boats in protecting the Panama Canal is pointed out.

Four new engines executed in twin form and giving 6000 to 7000 hp. each, or a total of 28,000 hp., are proposed for the flying boat. It is assumed that these engines can be produced in a limited quantity two years from now. Other basic characteristics of the super-airplane contemplated include: power loading 12 lb./hp.; wing loading 50 lb./sq.ft.; aspect ratio 9; $Cl_{max.}$ (with flaps) 2.5 abs.; gross weight 336,000 lb.; wing area 6720 sq.ft.; span 245 ft.; and minimum flying speed 88 m.p.h.

Disposal load, taken as 50 per cent of the gross, is divided as follows: crew, equipment, fixtures 8500 lb.; fuel for 20 hr. at 50 per cent maximum power 112,000 lb.; guns and ammunition 7500 lb.; bombs 40,000 lb.; total useful load 168,000 lb. Space would be provided to carry 100,000 lb. of bombs with a reduced fuel cargo allowing a range of approximately 10 hr. Cruising speed of 272 m.p.h. at 20,000 ft. would permit a range of 5400 miles. Weight of armament equipment, performance, design features, advantages of Diesel power plant and the cost and time necessary for production are considered. *Aero Digest*, October, 1940, pages 43–45, 1 illus., 1 map.

Longitudinal Stability and Control. S. B. Gates. Main features of longitudinal stability and control are described in the simplest possible terms, omitting the mathematical apparatus. Discussion covers: definition and construction of the neutral point; stick-fixed and stick-free stability with different types of elevator; dependence of stability on loading and flight conditions; neutral point variation and c.g. range for a twin-engine bomber with convergent elevators; interpretation of a neutral-point diagram in terms of the behavior of the airplane and the control angles and forces necessary to hold it at various speeds; and the question of how much stability. Appendix gives a classified list of some useful recent British reports on general theory, slipstream, bodies and nacelles, c.g. height, elevators, downwash and model-full scale comparison. *Aircraft Engg.*, September, 1940, pages 260–263, 4 illus.

Passenger Comfort in Commercial Aviation. W. W. Davies. Factors contributing either directly or indirectly to passenger comfort in a regular commercial airliner are presented, including space accommodations, interior design, noise prevention, heating and ventilating, lighting, catering, oxygen equipment, lavatory facilities, sanitation and fumigation, airplane operation and vibration. Table shows comfort limits as controlled by flight operation. *S.A.E. Jour. (Trans.)*, August, 1940, pages 342–348, 4 illus., 1 table.

Rotary-Wing Aircraft

The Case for the Single-Bladed Rotor. J. Lauderdale. If advantages of both giro and fixed-wing aircraft could be combined, an ideal aircraft would be approached. It seems that this could only be accomplished by utilizing a single-bladed rotor. Calculations are given which indicate that the type of rotor could be both started and stopped while the machine was in flight. Aircraft would be a monoplane of very high wing loading, of clean aerodynamic form, and with a retractable mounting for the rotor so arranged that when the blade is stopped in flight after take-off, it can be secured to the fuselage. Forces on the blade due to airflow and due to autorotation are estimated and required strength of the blade is calculated. Rotor blade does not have to be made as light as possible but should be of a definite weight calculated from the speed of rotation and coning angle desired in the formula given. To be concluded. *Flight, Aircraft Engr. Sup.*, October 3, 1940, pages 34–36, 8 illus.

Helicopter Theory. T. von Kármán. Construction of a suitable helicopter certainly presents greater difficulty than most inventors and constructors believe, but is nevertheless not without prospects. In the author's opinion the helicopter can only compete with fixed-wing aircraft when aircraft are required for purposes of observation or similar use necessitating hovering at low velocity. The advantage of vertical climb is offset by the lack of gliding ability in case of engine failure. The difficulty of stability in the case of free helicopters has not been encountered much so far because in general the aircraft have been unable to hover. A solution of the stability problem has so far been found only for captive helicopters in the form of tethering by several ropes.

Discussion includes: lifting power of a single rotor; comparison with fixed-wing aircraft; lift of a double rotor; helicopter in horizontal flight; stability of a single rotor and of a double rotor; stability of a captive helicopter; and gliding property of helicopters in case of engine failure. British Air Ministry translation No. 1041 from "Zeit. fuer Flugtechnik und Motorluftschiffahrt," No. 24, 1921. *Aircraft Engg.*, September, 1940, pages 271–276, 8 illus., 28 equations.

The Speed Cubic. R. M. Clarkson. Alternative solution to that given previously by K. Turner is presented which has been in use for over two years and has the advantage of being simple, quick, accurate, avoiding the use of awkward roots, and keeping the physical significance of the quantities in view. An expression is derived in terms of speed, drag, weight, atmospheric density, propeller efficiency, brake horsepower and span loading: $V = 121\ (\eta P/D\sigma)^{1/3} \times (1 \times r)^{1/3}$ where $r = (0.33 K \times W/\eta P \times W/S^2)/V \times \sigma$. Curves are presented for use in solving V. One curve gives the speed that an airplane would do if there were no induced drag. Equations are derived with respect to each of the four variables in turn and the relations are plotted on another graph. "This is a useful companion to the other graph and shows the relative sensitivity of level speed to the several variables which determine it; and demonstrates further the importance of the parameter r which controls this sensitivity." *Flight, Aircraft Engr. Sup.*, August 29, 1940, pages 32–33, 2 illus., equations.

Random Notes on German Aerial Troop Trailers or Aviation is the Coming Thing. W. S. Shackleton. Four of the 20-seat aerial trailers proposed could be towed behind a Junkers Ju. 52/3m. airplane. Design is described with computations to prove the idea feasible. Span is 82 ft., length 46 ft. 8 in., wing area 765 sq.ft., loaded weight 7000 lb., and wing loading 9.1 lb./sq.ft. The towing airplane and its train of trailers must be considered as one aircraft. A table shows the all-up weight, wing area, and wing and power loading for the Junkers Ju. 52/3m. under three conditions: with 14–17 passengers; when lightened for towing; and when suitably lightened and having a train of four gliders. Similar data are also given for each of the four gliders.

Advantages of such gliders from a military point of view, and how they could be used in transporting troops to Britain are discussed in great detail. *Aeroplane*, September 6, 1940, pages 271–274, 5 illus.

Stress Analysis and Structures

A Rational Definition of Yield Strength. W. R. Osgood, National Bureau of Standards. With the yield strength determined by conventional methods, it cannot be said in general for two structural elements geometrically alike but of different materials that similar loads, producing maximum stresses equal to the yield strengths in the two cases, are simply related to the yield strengths. A definition of yield strength is proposed which often has the advantage that, for geometrically similar structures of different materials, loads producing maximum stresses equal to the yield strengths are proportional to the yield strength. By defining suitably the yield strength, simple relations may be found between the damaging deformations or between the critical loads. This method of determining yield strength (in compression) has been used by the author for some years to compensate for variations in test results due to variations in the mechanical properties of the materials of the test specimens. A.S.M.E. paper. *Royal Aeronautical Soc., Jour.*, August, 1940, pages 653–656, 2 illus., 4 equations.

Tapered Tubing. T. C. Bennett, Naval Aircraft Factory. Design possibilities for more efficient construction by the use of tapered, formed and stepped tubing for structural members, are discussed and illustrated, including: methods of making cantilever tubular beams, when weight saving is a consideration, by use of telescoping tubes, step-tapered tubes, and tapered tubing; dimensional ratios of wall thickness and diameter obtainable in shaped and tapered tubing; effect of increased wall thickness at the end of the tube on column strength as indicated by results of tests on plain end tubes and of columns built up by welding on a heavier section at the end; tolerances to which heavy end tubes can be produced, and theoretical possibilities of some columns for weight saving and drag reduction in aircraft; percentage saved in weight and drag by tapering a Euler strut of constant thickness and a round strut of constant dimension and uniform taper in thickness; step-tapered tube for airplane landing-gear struts, by use of which it is possible to get the desired small section for the axle without the problem of making additional joints. *Product Engg.*, September, 1940, pages 400–403, 9 illus.

Aircraft Accessories

Design and Shop Problems in High-Pressure Hydraulic Systems. H. W. Adams, Douglas Aircraft Co. Paper previously abstracted from preprint. *S.A.E. Jour.* (*Trans.*), September, 1940, pages 367–369, 3 illus.

Aircraft Alighting Gear

TESTING APPARATUS

Drop Test of Shock Absorber. W. C. Trautman. High-speed photographic recorder developed at Bendix Aviation, Ltd., for use in drop tests of shock absorbers, is based on the principle of the ultra-high-speed camera. Pin-point light sources are provided on the fixed portion of the shock absorber, which is mounted in the drop-test rig, on the wheel axle, and on two reference points on a fixed standard which is usually placed about 12 in. to one side of the shock absorber. When the shock-absorber and wheel combination is dropped in a darkened room the lights on the shock absorber and wheel axle trace light paths which have relative movement, one with the other, and with respect to the two fixed standard lights. The light patterns are photographed as dots by using a motor-driven shutter on the camera to break up the light source. To avoid congestion on the film caused by having these points fall in a straight vertical line, the camera is mounted on a rigid pivot and "fanned" in a horizontal plane during the time of drop. Description of apparatus. *Aviation*, October, 1940, pages 55, 94, 2 illus.

Aircraft Manufacture

Aircraft Jig Design. Comprehensive tooling equipment employed in the manufacture of the Blackburn Skua dive-bomber monoplane for the Fleet Air Arm is described. Extensive use is made of large cast-iron members in the construction in place of the more customary structural-steel sections, and considerable forethought has been given to accessibility. Trunnion mountings are employed on many of the assembly jigs and those of rigid construction are of open-sided design, resulting in jigs affording a maximum of accessibility and permitting the largest possible number of operatives to work upon them. *Aircraft Production*, September, 1940, pages 277–282, 22 illus.

Jigs at Republic. Jigs used by the Republic Aviation Corp. to speed up aircraft production are illustrated with brief descriptions. *Aviation*, October, 1940, pages 36–39, 15 illus.

Forming Aircraft Sections. Aircraft channel member formed in accordance with recommendations by the Technical Advisory Service of the British Northern Aluminum Company is illustrated and discussed. *Aircraft Production*, September, 1940, page 295, 1 illus.

The Forming of Aluminum-Alloy Sheet. Some frequently-ignored, but important, points which must be taken into account in the forming of high-strength aluminum-alloy sheet to the profiles required in stressed aircraft components are discussed. Choice of alloy and of correct heat-treatment procedure, and the risk of grain growth are taken up. The necessity for considering the relatively high coefficient of friction between aluminum and steel is pointed out. It is shown that where risk of failure by cracking, dragging or tensional rupture exists it is important that a high polish be given to the tools and that a suitable lubricant be used. Choice of the most liberal bend radius permissible in all cases is recommended. A further advisable precaution is to ensure that the sheet conforms closely to the profile of the tool, since otherwise a bend of sharper radius than that intended will result. Illustrations cover: coarse grain in the coating of Alclad sheet after heat treatment and satisfactory grain in core material after the coating has been removed; drawing indicating where a good polish on the tools is essential; flattening operation showing tendency of aluminum alloys to form a "peak" radius unless suitably constrained; relationship of direction of rolling and minimum bend radius, indicating that sharper bends may be produced at top and botton flanges than at the sides (in direction at right angles to that of rolling); and bending nearly parallel with direction of rolling as a contributory cause of failure in a sheet to B.S.S. 5L3. Tables show solution-treatment soaking periods and minimum bend radii for aluminum-alloy sheet. From "Normal News." *Aircraft Engg.*, September, 1940, pages 283, 285, 5 illus., 2 tables.

Magnesium Alloys in the U.S.A. L. B. Grant. Abstract of S.A.E. National Aircraft Production Meeting paper presented on October 7, 1939, and previously abstracted from preprint. *S.A.E. Jour.* (*Trans.*) August, 1940, pages 325–331, 3 illus., 7 tables. *Aircraft Engg.*, September, 1940, pages 279–282, 3 illus., 7 tables.

Pressed Aluminum Alloy Aircraft Dome. H. T. Burke. At the plant of the Worcester Press Steel Company a dome was developed by the cold-press drawing process from a new light aluminum alloy, 61S, suitable for forming vital parts for aircraft construction. Composition, and physical and mechanical properties of the alloy are given, its heat treatment is discussed and drawing process is described. Alloy was particularly adapted to this development by virtue of its excellent cold-forming characteristics, its high strength obtainable by heat treatment and its good resistance to corrosion which is superior to that of 17S-T. A.S.M.E. paper. *Metal Industry*, September 20, 1940, pages 226–227, 3 tables.

Production Checks in Manufacture. German control of quality and interchangeability is discussed with illustrations of special assembly gages in use. Work of the checker, a highly-specialized engineer who applies an overriding inspection of assembled and unassembled components and their interchangeability, is described. Among the duties of such checkers is the examination for cleanliness of parts and variation of dimensions occasioned by surface treatments. Method of checking grain flow in the production of light-alloy forgings and die pressings is pointed out. Illustrations cover: checking the distance between aileron hinges on a Junkers double-section wing, a ball-center measuring device for checking distance between surface and center section of a wing; a straight-edge used to check alignment of pick-up points on wings; and mirrors for examining riveting and to observe whether screw joints at inaccessible places are properly secured. *Aircraft Production*, September, 1940, pages 301–302, 6 illus.

Work of the Loft in an Aircraft Plant. F. M. Gibian, Northrop Aircraft, Inc. Lofting, or "lines-work," is developing full-scale contours or shapes of an airplane from a designer's sketches, and includes the building of a full-sized mockup and all templates. This work is described in detail. A method for laying out body plan lines, which has been developed at Northrop, is explained. It uses Alclad and promises to speed up new aircraft production by cutting down the time usually required between design and fabrication stages. *Aero Digest*, October, 1940, pages 76, 79, 4 illus.

Heat-Treatment of Aluminum Alloy Sheet. Importance of correct heat treatment of aluminum alloys in minimizing manipulative difficulties during fabrication in the form of sheet or strip is emphasized. It is pointed out that salt baths possess many advantages for solution heat-treatment purposes, and a salt bath with automatic salt ejector is shown in a drawing. Working precautions are given in full detail. For annealing processes forced-air circulation furnaces are preferred. Chemical composition and mechanical properties of a natural aging alloy Na.17S and a double-heat-treatment alloy Alclad Na.21S are presented in a table. *Metal Industry*, September 13, 1940, pages 202–205, 5 illus.

Men and Machines. New exhaust equipment installed at the Monarch Machine Tool Company employing a downdraft ventilating system making it possible to grind, spray-paint and sand castings within a few feet of precision machining operations. Oilgear two-way three-position electric-controlled variable-displacement pumps. Lake Erie hydraulic press with a capacity of 1700 tons. Hydraulic Press 650 ton triple-action blankholder press for deep drawing gasoline tanks and similar aircraft parts. Standard Electric infinitely-variable-speed buffing and polishing machine. Hisey-Wolf improved direct-drive disc grinder. Short descriptions of this equipment and references to news items of equipment recently announced. *Automotive Industries*, September, 1940, pages 261–263, 282, 7 illus.

Spot Welded Aluminum Aircraft Structures. C. W. Dodge, Vought-Sikorsky Aircraft. Detailed data on welding time, pressures and heats for spot welding aluminum are presented. Design specifications for spot-welded joints are given, including: design values for shear strength of spot welds in 24ST Alclad and 52S1/2H aluminum-alloy sheets; test and design values for tensile strength of spot welds in 24ST Alclad for various sheet thicknesses; minimum dimensions for efficient spot welding or aluminum alloys of various sheet thicknesses; spacing of spot welds in single row for assemblies that are not major structural parts of airplanes; test strengths of spot welds and rivets for various thicknesses of material, and typical defects in spot welds if correct welding technique is not followed; means to prevent buckling of a large spot welded panel; and precautions in regard to condition of surfaces to be welded. *Product Engg.*, September, 1940, pages 388–392, 12 illus.

Refrigeration in Aircraft Engineering. The Prestcold special-purpose low-temperature refrigerator described is used by a leading British aircraft constructor for the continuous cooling of bushes to a temperature of —80°F. Bushes pass through the cabinet at the rate of 64 an hour. *Aeroplane*, September 13, 1940, page 300, 1 illus.

MANUFACTURING EQUIPMENT

New Equipment. Bliss 800-200-ton hydrodynamic double-action press. Cullen-Friestedt Model 12 welding positioner with capacity for 1200 lb. Bakewell precision tapping machine. Whistler adjustable die sets. Stanley soft-face hammers for use on light-metal sheet. Neilsen layout punches and transfer screws. Colonial 1 to 10 ton capacity hydraulic presses. Kato d.c. motors for driving equipment and also for furnishing 60 cycle a.c. current for operation of an auxiliary equipment. Croft bearing washer. Cutler-Hammer drum-type master switch providing three-wire control for machine tools. Tonnage indicator for Steelweld bending presses. Westinghouse fluorescent fixture for continuous strip lighting. Ingersoll-Rand D-60 portable two-stage air-cooled 60 cu.ft./min. compressor. Powerlox leather paste providing nonslip pulley facing. Lake Erie double-slide hydraulic press of 170-ton capacity. Grob improved filing machine. Tannewitz bandsaw with hydraulic brake. Duffy univertical high-speed end-milling machine. Hobart motor-generator d.c. arc welder, specially designed to meet requirements for production welding in aircraft factories. Dykem paste for use in testing bearing surfaces. Milburn Type FF twin-stage regulator. U.S. Electrical test stand for pumps and generators. Blackhawk Nuggies midget socket wrenches. Chicago Pneumatic reversible wrenches. Paascho Cub airbrush adjustable for pressure and consumption. Scherr Magne-Blox universal angle iron. Long and short descriptions of this equipment. *Aero Digest*, October, 1940, pages 182, 185–186, 189–190, 193–194, 197, 14 illus.

Modern Machine Tools. Latest British additions to the range of factory plant are described. Midland Midsaw HNF horizontal bandsawing machine for light alloys and other nonferrous metals. Herbert No. 46V vertical milling machine specially designed for heavy-duty work. Hey multiple cam profiling machine. Rowland Type CO hydraulically-operated abrasive-wheel cutting-off machine for hard and high-speed steel bars. Ormerod 26-in. stroke heavy-duty slotting machine. Vomag German vertical machines for fine milling. *Aircraft Production*, September, 1940, pages 304–306, 8 illus.

Shop Equipment and Small Tools. Some modern aids are suggested for efficient British aircraft production. Guyson Vac-Lok-Grip for handling metal sheet. Salford electrical micrometer for measuring the thickness of foil or sheet metal. Colt blackout ventilation. Mann Egerton electrically-operated tank especially developed for cleaning carburetor parts. Pressed Steel special-purpose Prestcold refrigerator used to cool bushes to a temperature of 80° for interference fits. Burston quick-action adjustable spanner. Titan stud runner having adjustable depth stop and taper sleeve which brings the driving rollers automatically into contact with the stud. Blackhawk aircraft jack specially designed for aircraft work and having wheel castors which may be telescoped into the base. *Aircraft Production*, September, 1940, pages 292–293, 7 illus.

Men and Machines. H. E. Blank, Jr. Equipment in the recently established plastic laboratory of the Hydraulic Press Manufacturing Company. Standard Gage dial indicators equipped with new shockproof mechanism and sensitive low-friction movement. Federal modified form of the regular Model 45 B-60 pitch-diameter gage. Toledo machine to be used in testing Ford automobile-chassis springs. Lees-Bradner chucking-type thread-milling machine that generates threads by means of the hob or ring-type thread-milling process. Bliss 800-200-ton hydrodynamic press with universal electric control and an auxiliary hydraulic pressure cushion in the bed. Hardinge high-speed precision lathe. Grob heavy-duty continuous-motion filing machine. Short descriptions of these machines and references to other tools on the market. *Automotive Industries*, October 1, 1940, pages 296–297, 404–407, 8 illus.

Aircraft Performance Testing

The Theory of Position Error. J. Lockwood Taylor. Airspeed indicator gives correctly the velocity, relative to the aircraft, of the air at the position selected for the pitot, but this differs from the free-air velocity by the amount of the local air velocity set up by the aircraft itself. This local velocity and its variation with the speed of the aircraft are considered in order to throw light on the so-called position error and to facilitate the interpretation and reduction of flight observations. Speed deviation due to the error occurring in the static head is split into two parts, one due to streamline flow without circulation, and the other to circulation around the wing. The equation $dV = aV + b/V$ (where a and b are constants) is derived for total position error. This equation is rewritten into a form for plotting, a single curve applying to all weights and heights. It is assumed that results of observations of ground speed, or of flight tests using a suspended static head to give corrected readings, are available. To evaluate the constants a and b, a linear method of plotting is given whereby observed position errors multiplied by the indicated airspeed give a straight line when plotted against indicated

airspeeed squared, from which the constants can be deduced. Effect of a slight departure from unity of the value of the calibration constant for the total head tube is also pointed out. *Flight, Aircraft Engr. Sup.*, August 29, 1940, page 32, equations.

Aircraft

The Need for Research. A flying destroyer, big by present standards, designed to combat the motor boats operating from just across the Channel, to deal with tanks, and to sink ships, and having long-range armament of serious cannon to sink ships, armor protection, and heavy loading; better fighter and bomber armament; a bomber with same load and gun power as the Wellington but half as fast again, and with armor protection and cannon; dive bombers, fast, armored and having tailguns; for night operation a device to enable fighters to pick up invisible enemy bombers; a special night interceptor; tricycle undercarriage to avoid night-landing crashes; higher-flying fighters and bombers; and a scout reconnaissance airplane capable of an hour's flight at 550 m.p.h. These are the needs of the British air force which research and development should be producing. They are discussed and some suggestions made.

Evidence is given in a table indicating that British aircraft are not superior in speed and load to German aircraft. British superiority in fighting is explained by better training of men, greater determination to fight, superior armament and greater maneuverability of fighters. Question is considered of what would happen if the Germans developed or redesigned equipment to produce better armament, night-patrol fighters, aircraft detection methods to enable night fighters to locate British bombers, and a bomber which would cruise, however slowly, around 3000 ft. above the maximum ceiling of British fighters.

Maximum speeds, duration and, in the case of bombers, the loaded weight of the following are compared in a table: Fighters—Spitfire (387 m.p.h., 3.6 hr.), Heinkel He.113 (400 m.p.h.), Hurricane (335 m.p.h., 4½ hr.), Me.109E (354 m.p.h., 2¼ hr.), Blenheim IV (295 m.p.h., 8¾ hr.), and Mo.-110 (365 m.p.h., 7 hr.); Bombers—Wellington (265 m.p.h., 18 hr., 27,000 lb.), He.111K IIA (252 m.p.h., 27,247 lb.), Hampden (265 m.p.h., 8½ hr., 18,756 lb.), and He.111K VA (274 m.p.h., 12 hr., 27,247 lb.); and Dive Bombers—Skua (225 m.p.h., 8230 lb.), and Ju.88K (317 m.p.h., 5¼ hr., 17,000 lb.). *Aeroplane*, September 20, 1940, page 317, 1 table.

Aviation Sketch Book of Design Detail. Drawings show the construction of parts of aircraft. First issue—fin of the Boeing 307 Stratoliner which is made in two sections, the forward portion or dorsal fin being a permanent installation in the fuselage; stabilizer of the Fairchild PT-19 trainer; stabilizer of the Johannson light airplane constructed of bonded plywood; engine mounts of the Fairchild PT-19, of the Messerschmitt Me.109, and of the Ardo Ar.96B two-place trainer similar in size and shape to the PT-19.

Second issue—Fowler flaps on the Lockheed transports and Hudson bombers, consisting of auxiliary airfoils located on the under side of the wing near the training edge; flaps with the hinge-type control on the Douglas DC-3; engine mount used on the Stuka Junkers Ju.87 dive bomber for the Jumo engine and standardized on various German planes; aluminum-alloy rib construction used on the Douglas B-19 210-ft. wing-span bomber; and leading edge of the B-19, showing rib construction used, the stringers being of "H" section with every third rib reinforced. *Aviation*, August and October, 1940, pages 70–71 and 56–57, 11 illus.

Fighter Ideas (German and British). Blohm and Voss Ha.137 single-seater fighter-dive bomber (680 hp. Jumo 210C liquid-cooled engine) of 1937 is remarkably similar in design to the British Supermarine S.7/30 single-seater fighter of 1936 (from which the Spitfire was developed), and suggests some copying of the design. Likeness extends to the downswept wing roots, fairings for the fixed undercarriage, and lines of the fuselage. The Ha.137 has a top speed of 205 m.p.h. and span of 36 ft. 7 in. The "shoots" on the wing tips are radio masts. The S.7/30 had a top speed of about 230 m.p.h. and span of 46 ft. Photographs only of the Ha.137 and S.7/30 fighters. *Aeroplane*, September 20, 1940, pages 324–325, 2 illus.

Performance on the Level. C. R. Tennant. Horsepower, wing and power loadings, maximum speed and designed altitude and maximum speed corrected to 17,500 ft. are given for the following British, French, German and American fighters (maximum speed corrected to 17,500 ft. being given in parentheses): Spitfire using 100-octane fuel (387 m.p.h.); Heinkel He. 112U (380 m.p.h.); Me. 109 (375 m.p.h.); Me. 110 (369 m.p.h.); Spitfire I (367 m.p.h.); Focke-Wulf Fw. 198 (362 m.p.h.); Dewoitine D-520 (358 m.p.h.); Hawker Hurricane I (336 m.p.h.); Heinkel He. 112 (324 m.p.h.); Curtiss Hawk 75A (321 m.p.h.); Morane Ms. 406 (320 m.p.h.); Bloch 151 (308 m.p.h.); and Gloster Gladiator (256 m.p.h.).

Functions of the fighter, and the reasons for computing maximum speed at 17,500 ft. for comparison are discussed, and comments are made on the performance of these airplanes. The twin-engine Me. 110 has had fair success against bombers but lacks maneuverability. "The two-motor fighter gets into a rather tight vicious circle of more power, more weight, more wing area, that makes it hardly worthwhile unless it can carry really heavy armament. The Bell Airacobra and the Lockheed XP-38, for instance, are both single-seaters with a maximum speed of 404 m.p.h.,.....the only advantage of the twin-engine type being its greater range. There seems little excuse for building a single-seat twin, as the all-up weight is not likely to be less than about 10,000–12,000 lb., and the additional weight of a gunner and turret is not serious, whilst the additional fire power they provide is valuable, particularly as the two-motor fighter has hardly the maneuverability to take full advantage of its fixed guns, a fact which has been proved in the case of the Me. 110." Side views of the Spitfire, Hurricane, Boulton-Paul Defiant two-seater, Heinkel He. 113 (1500-hp. D.B. 601 engine), Me. 109, and Messerschmitt Jaguar fighter-bomber (two 1150-hp. D.B. 601 engines) are included for comparison. *Aeroplane*, July 26, 1940, pages 98–99, 6 illus., 1 table.

Identification of British and German Aircraft. Fourteen silhouettes, photographs and drawings each are given for the Lockheed Hudson reconnaissance bomber and for the Messerschmitt Jaguar reconnaissance bomber, with a few details regarding each. The Jaguar has an all-metal structure, is powered by two D.B. 601A engines each developing 1150 hp. for take-off, and rated at 980 hp. at 14,760 ft., and carries a crew of three. Under surfaces are colored light grey, sides and top surfaces black. Span 55 ft. Length 35 ft. Maximum speed about 320 m.p.h. at 16,000 ft. *Aeroplane*, August 9, 1940, pages 144–145, 28 illus.

Germany

Development in Germany. Three new fighters and five new bombers, as well as several improved engines are in production in Germany. The Heinkel two-engine high-speed fighter is built on the all-wing principle. Crew of two lie flat in the wing and look through the leading edge. This has been done to make possible the use of a fairly thin wing and yet do away with the fuselage. Prone position of the crew materially increases their ability to withstand high acceleration without blacking out. Top speed of around 430 m.p.h. has been quoted. Two Jumo 211 engines mounted in the wing drive the propellers through shafts. Propellers are more likely to be pushers to obviate compressibility effects at high speed, but this is not definitely known. Tail unit is carried on a single boom. Airplane is thought to be intended as a high-speed long-range heavily-armed fighter or as a high-speed undefended bomber. Heinkel is believed to have two new bombers under way, the He. 119 (two 2000 hp. D.B. 605 X engines, a top speed of around 300 m.p.h.), and the other reputed to have four engines mounted in tandem in the wings (considered as unlikely as Heinkel condemned the idea some time ago).

Great things hoped for the Focke-Wulf Fw. 198 single-seater tricycle pusher fighter apparently have not been fully realized. The 1500-hp. D.B. 603 engine has a turbo supercharger rated at 21,000 ft., and drives a pusher propeller through a shaft 4½ ft. long. Removal of weight of ammunition from the nose when the single cannon is fired moves back the c.g. of the airplane to such an extent that it becomes unstable. Four machine guns are located in the wings. Drawing of the Fw. 198 is given. The Fw. 189, two-engine airplane designed on the lines of the Fokker G.1 and intended for army cooperation work, is not formidable. Company is known to be working on a bomber development of the Fw. 200K Condor with four 1200 hp. Jumo 211A engines. Nose and tail are new and have gun turrets. Bomber Condor (top speed 270 m.p.h.) was first in action in the attack on Scapa Flow on March 16, but has been held in reserve.

Dornier Do. 215 has been strengthened to take two 1500 hp. D.B. 603 engines and will have a top speed of about 335 m.p.h. Do. 17s are being equipped with a power-operated gun turret on top of the fuselage. The extinct Do. 19 bomber is reported to have been revived and with four D.B. 601 engines has fairly high performance. The Do. 29 two-engine attack bomber having a twin tail with tailplane of marked dihedral has been reported again.

Henschel two-engine dive bomber in production has been developed from the Hs. 124, and has been reported in action off Norway already. It is designed to carry one 2205 lb. bomb for action particularly against ships.

Messerschmitt is believed to be developing a big four-engine bomber. Some form of assisted take-off is likely as both Heinkel and Messerschmitt have made experiments with mobile catapults. The Me. 115 fighter (1500 hp. D.B. 603 engine), now coming into production, has a wing which is modified in shape (reduced to a span of 31 ft. 3 in.) and fitted with a new form of flap (possibly a venetian-blind flap).

Production of the Junkers Ju. 89 and Ju. 90 is not going forward but production seems concentrated on Ju. 87s and Ju. 88s at present. A very big Blohm and Voss four-engine flying boat crashed on its trials early this year. Developments are probably going forward in this direction and also for a single-engine dive bomber. A number of the Ha. 138 three-engine flying boats have been built for use in the Baltic as well as a number of four-engine Bv. 142 troop carriers.

All German aircraft engines have direct injection. Mercedes-Benz is going into production with the D.B. 603 12-cylinder inverted-Vee engine of 1500–1700 hp. The 2000-hp. D.B. 605 24 cylinder X engine is meeting with manufacturing difficulties. Turbo-superchargers are being fitted to both these engines and to the D.B. 601S. B.M.W. has a 1500 hp., 18 cylinder air-cooled two-row radial which is supposed to be giving trouble. Junkers has a 2000 hp., liquid-cooled engine and a 1050 hp. Jumo 206 Diesel which seems to be about the best thing in that line. *Aeroplane*, August 30, 1940, pages 236–238, 1 illus.

Modern German Bomber. Specimen of the Junkers Ju. 88, built in 1939 and recently shot down in Britain "has some features strange to British eyes .....but if Junkers design with its concentration of load at ball joints may be said to stand at one end of the scale, then American design with its joints frequently made by a multiplicity of small screws, stands at the other extreme. In England we have examples of both." Mainplane joint has two ball joints to each of the two spars, tensile and compressive loads of the spa flanges being transmitted through these balls with their mating sockets. With the completely transparent nose in front of the pilot, visibility forward and downward is excellent, view downward extending even to between the rudder pedals. Instruments are not liberal and instrument equipment is not nearly as elaborate as in the modern airliner. Fuselage nose is blunt and composed of flat panels of nonsplintering glass, not bulletproof. Engines are two Jumo 211 gasoline-injection inverted-vee twelves. Area of trimming tab (and this applies to all control surfaces) is large in proportion to rudder area. All control surfaces are fabric covered.

Structure, crew stations and their equipment, instruments on board and missing, arrangement of controls, tail unit, and general design are described. Drawings show: inflatable rubber boat; cooling-fluid and oil radiators arranged in circular fashion in front of the inverted vee-12 engine; rudder pedal and brake cylinder mounted as an assembly on an adjustable slide; throttle lever with three means of adjustment, two coarse and one very fine adjustment required for gasoline-injection engines to control amount of gasoline pumped into the cylinder; aileron control by bevel gear and shaft drive; rear two of four ball joints attaching fin to fuselage; leather bellows joining the warm air intake to the supercharger to provide flexibility and to allow some movement; and typical ball joints used to connect wing spars at the main joint, ball being held into the socket by a screwed ring which can be turned by holes around its circumference. *Flight*, October 3, 1940, pages 270c, 270d, 271, 11 illus.

The Focke-Wulf Family. Before the Royal Air Force bombed its works (so intensively that production must have practically ceased) the Focke-Wulf company was known to have in production the Fw.58 Weihe two-engine training monoplane, the Fw.187 "Destroyer" two-engine fighter, the Fw.189 two-engine general-purpose monoplane, the Fw.198 single-seater pusher fighter, and the Fw.200K Condor, a military version of the four-engine civil transport. The Fw.187, 189 and 198 are described in regard to purpose, construction, engine, performance, armament and, in some cases, weights and dimensions.

Fw.187 Destroyer—two D.B. 601 or Jumo 211 1150 hp. engines. Top speed 360 m.p.h. Climb to 19,700 ft., 5.8 min. Absolute ceiling 38,600 ft. Armament, either six 0.303 machine guns, four 0.50 machine guns, or two 20 mm. shell guns all fixed to fire forward, one rear movable machine gun, and no under gun. Fw.189 general purpose airplane—two 450 hp. Argus As.-410 12 cylinder engine. Top speed 223 m.p.h. at 8600 ft. Disposable load 1565 lb. Climb to 19,680 ft., 14.8 min. Absolute ceiling 27,550 ft. Armament, two fixed machine guns, guns under nose of central nacelle, and one movable machine gun on top to fire forward, other to fire aft. Fw.198 all-metal pusher fighter—1500 hp. D.B. 603 engine with propeller shaft 4½ ft. long. Tricycle landing gear fully retractable. Top speed 373 m.p.h. at 19,680 ft. Initial rate of climb 2755 ft./min. Service ceiling 34,440 ft. Maximum range 590 miles at 295 m.p.h. Disposable load 2942 lb. The Fw.187 and Fw.189 are illustrated.

Both Focke-Wulf factories cover a very large area but have been repeatedly attacked by the R.A.F. Success of the attack may be why so little has been heard of its products in action recently, although four-engine bombers reported over England recently are almost certainly Fw.200Ks. Swiss reports indicate that several squadrons of the Luftwaffe have been equipped with the Fw.198 fighter, speak of it as having been in action, and credit it with fabulous successes, but it has not been mentioned as in action by the British Air Ministry. *Aeroplane*, September 20, 1940, pages 324–325, 2 illus.

Photograph only of the Focke-Wulf Fw.187 twin-engine fighter reported to have a top speed of 362 m.p.h. *Aviation*, October, 1940, page 74, 1 illus.

GREAT BRITAIN

The Fairey Fulmar. Fairey Fulmar two-seater fighter monoplane (1145 hp. Rolls-Royce Merlin X engine with two-speed supercharger) is a faster and more formidable airplane than any previously possessed by the Royal Navy, and the eight machine guns in the wings make it "the most heavily armed two-seater fighter in the World." The Fulmar was developed from the Fairey P.4/34 two-seater fighter-bomber and, from outside appearance, differs from it only in that the radiator has been moved forward under the nose and the tailplane set lower on the fuselage in front of the fin and rudder. Tunnel-ducted radiator under the nose is divided into two cylindered sections with oil cooler between them and carburetor air intake in front. Undercarriage retracts inwardly. Performance of the Fulmar is even better than that of the P.4/34 (speed 284 m.p.h. at 17,200 ft. with full load of 1000 lb. of bombs, range 1000 miles at 230 m.p.h.). P.4/34 multigun fighters, supplied to the Danish Navy and generally similar to the Fulmar, had a top speed of more than 300 m.p.h.

The Fulmar was one of two new types reported in action for the first time recently. Fairey Albacore three-seater torpedo-spotter-reconnaissance biplanes, operating with the Coastal Command, raided quays and sidings at Boulogne, while in the Eastern Mediterranean five Junkers Ju. 87B dive bombers were shot down by Fairey Fulmar and Gloster Gladiator fighters of the Fleet Air Arm. Two short notes. *Aeroplane*, September 13, 1940, page 281, 1 illus.

The Hawker Hurricane. In a year of war Hurricane squadrons had scored something like 1500 confirmed victories over German fighters and bombers. Evolution of the Hurricane fighter is traced and a very long detailed description is given with many photographs, a cutaway drawing, and characteristics and performances of the Hurricane Mk.I powered with a 1030 hp. Rolls-Royce Merlin III engine.

A second article, entitled "The Building of the Hurricane in Canada," presents a number of photographs taken in the Canadian Car and Foundry plant in Montreal. A third article, entitled "A Hurricane in the Hand," describes its performance in flight. *Aeroplane*, September 6, 1940, pages 254–265, 42 illus., 1 table.

38 Types in 25 Years. Accomplishments of the Westland Aircraft Company during the past 25 years, during which a remarkable versatility in range of designs was attained. Various types are described and illustrated, including the Hill Pterodactyl tailless-type monoplanes. *Flight*, September 12, 1940, pages 204a–204h, 205–206, 38 illus.

ITALY

A Standard Italian Bomber. Designed for bombing and reconnaissance, the B.R. 20 is an all-Fiat product and differs from several Italian bombers in that it has been designed to an orthodox formula. It is a twin-engine monoplane of clean design with twin fins and rudders and mixed construction. Modifications have been made to the nose the lower portion of which is practically all transparent. Maximum bomb load of 3500 lb. can be carried. Defensive armament comprises a 12.7 mm. gun in a Breda power-driven turret in the nose, two guns in a retractable turret on top of the fuselage and a fourth gun in the lower part of the fuselage aft of the wing. "It does not appear that the trailing edge flaps are remarkable for their effectiveness." Minimum speed is given as 77.6 m.p.h. without flaps and 68.4 m.p.h. with flaps down.

Two Fiat A80 R.C. 41 engines developing 1000 hp. for take-off. Wing span 70 ft. 9 in. Wing loading 28 lb./sq. ft. Disposable load 7900 lb. Maximum speed at 13,000 ft. 264 m.p.h. Service ceiling after release of bombs and consumption of some of the fuel 32,800 ft. Climb to 19,700 ft. in 23 min. Range at 210 m.p.h. and 13,000 ft. 1240 miles. Description of bomber and engine, figures for dimensions, weights and loadings, and performance; and brief comparison with the Wellington bomber. *Flight*, August 1, 1940, pages 90–92, 6 illus.

SOUTH AMERICA

Flying Tanker. What is probably the first airplane to be devoted exclusively to the transport of fuel oil has been put into service by Transportes Aereos Centro Americanos. To avoid the heavy weight of the usual steel oil drum, oil is transported in bulk in a 600-gal. tank in the cabin of the airplane. Cabin of the Ford trimotor used was strengthened in the floor immediately under the high wing and the load was carried up to the wing by bracing. Tank itself is of rectangular proportions and about 4 ft. deep. It is criss-crossed internally with a honeycomb of baffleplates arranged vertically in two directions and also horizontally, to minimize swirl and to strengthen the flat sides. The cubic "cells" so formed are about 9 in. each way and communicate with each other by means of large holes in the baffles. In the bottom are two valves, one a safety valve for dumping. Unloading is accomplished through the other valve in 6 min. into underground storage tanks built at each airport. Loading takes 8 min. Brief reference from "Western Flying." August. *Flight*, September 19, 1940, page 233.

U.S.A.

Flying Types from America. Pilot who has flown two of the American types ordered for the L'Armée de l'Air and now arriving in England, reports enthusiastically on the Douglas DB-7 with its tricycle undercarriage. He says its performance is about equal to that of the Bristol Blenheim, or a shade better, and that it is excellent to handle. He describes the take-off as like that of a scalded cat, but says the DB-7 has the true tricycle simplicity of landing and is really a lady. Its only real fault is terrifically violent brakes and as the nosewheel is not steerable, but castoring against a damper, his first attempts at steering on the brakes at the start produced a somewhat erratic motion. *Aeroplane*, July 26, 1940, page 99.

American Miscellany. Types of American aircraft already in Britain are described with photographs including: the Brewster Buffalo XF2A-1, originally designed as a shipboard fighter; Curtiss Hawk 75A fighter and the Helldiver scout-bomber; Northrop A-17 attack bomber; Martin 167F high-speed bomber or long-range reconnaissance airplane; and Douglas DB-7 Boston bomber. *Flight*, September 19, 1940, pages 224c–224f, 13 illus.

The Lockheed Fighter. Reports imply that the British version of the Lockheed P-38 tricycle fighter on order for the R.A.F. may be arranged as a two-seater fighter with an aft gun turret. Possibly, too, the production order is for machines with Rolls-Royce Merlin engines in place of the "comparatively untried 1090 hp. Allison V-1710-C15 motors." Official figures are given for the dimensions, weights, loadings, armament and performance of the P-38. Maximum speed of 404 m.p.h. at 16,000 ft. is said to be obtained with a very heavy wing loading. *Aeroplane*, August 30, 1940, page 237, 2 illus., 1 table.

Engineering Fairchild's PT-19. A. Thieblot. Preliminary design and research work connected with the development of the Pt-19 trainer, in production for the U.S. Army Air Corps, are discussed. A study of the stall and flight characteristics at or near the stall was the prime objective. A full-size airplane was built and results obtained in flight tests led to a specific design. These tests and results, structure, production design, landing gear, and fuel and oil system are described in detail.

Protective-coating problems which had to be solved to obtain a finish for the all-plywood wing of the PT-19, and results obtained are discussed in a second article by R. B. Anderson entitled "Protection of Aircraft Plywood." *Aero Digest*, October, 1940, pages 130–132, 134, 137, 138, 15 illus., 3 tables.

New Curtiss P-40. A few details referring to structure, undercarriage, power plant, and propeller, as well as cutaway drawing and photographs. *Aviation*, August, 1940, pages 60–61.

Army Photographic Ship. Beechcraft Type F-2 specially designed photographic airplane is described in great detail including photographic and other equipment. Cutaway drawing shows location of equipment. *Aviation*, August, 1940, pages 64–65, 146, 3 illus.

The Monocoupe "Zephyr." Designated as the "Zenith," the Monocoupe Model 90-A twin-engine monoplane trainer will have two Lambert radial engines, and as the "Zephyr" two inverted inline Menasco D4S supercharged engines rated at 150 hp. at 2260 r.p.m. at 3000 ft. For military work it has been designed for transition training, will be powered by the Menasco engine installation, and will be known as the "Wild Cat." Airplane is described with specifications and performance data for the Menasco-powered Monocoupe "Zephyr." Wing span 36 ft. Useful load 1265 lb. Payload 623 lb. Gross weight 3365 lb. Maximum speed 180 m.p.h. Cruising range 565 miles. *Aero Digest*, October, 1940, pages 75, 128, 3 illus., 1 table.

1941 Luscombe. New all-metal trainer, powered by a 65 hp. Lycoming engine, is capable of 102 m.p.h. and lands at 35 m.p.h. Wing span 35 ft. Range 375 miles. *Aviation*, October, 1940, pages, 60, 106, 5 illus.

Interstate "Cadet." Production schedule of 600 planes has been set for the first year of operation by Interstate Aircraft and Engineering Corp. The Cadet two-seater high-wing strut-braced monoplane for sport or training is described. Continental 50 or 65 hp. engine. Wing area 173.8 sq.ft. Wing loading 6.91 lb./sq.ft. Maximum speed 114 m.p.h. on the 65 hp. engine. *Aviation*, August, 1940, pages 77, 146, 4 illus., 1 table.

Swallow Low-Wing Trainer. Swallow Model LT65 low-wing tandem-seater monoplane is described with specifications and performance data on the model powered with the Continental 65-hp. engine. Wing span 27 ft. Wing loading 9.4 lb./sq.ft. Maximum speed 115 m.p.h. Landing speed 40 m.p.h. Cruising range 350 miles. *Aero Digest*, October, 1940, page 113, 1 illus.

Air Transportation

American Airlines Trains Its Rookies. Methods employed by American Airlines at LaGuardia Field in training over 200 men and women. *Aviation*, October, 1940, pages 44–45, 126, 5 illus.

Air Lines in War. France has restarted several air services in unoccupied territory and, according to the Lyons radio, is to reopen services to French West Africa and French Equatorial Africa. Italian air service to South America is said to be running regularly. Soviet Russia has opened a service recently to Petropavlov which needs but two more stages to bridge the Behring Sea to Alaska. Japan is starting experimental services this month on its new routes to the Japanese Mandated Islands in the South Seas. Comments on these services and on routes operated by Pan American Airways. *Aeroplane*, August 30, 1940, page 238, 1 illus.

Airships

Goodyear Blimps. R. G. Picinich. Details of various blimps and their successful operation over a score of years. *Aviation*, October, 1940, pages 49, 120, 5 illus.

Gliders

Schweizer Two-Place All-Metal Sailplane. Schweizer Model SGS 2-8, first two-place all-metal sailplane to receive C.A.A. approval, has already been credited with a national distance record of 217 miles, and a world's altitude record of 20,000 ft. above sea level. Sailplane is a high-performance type, applicable for training and soaring, and departs from the type of cantilever gull-wing and wooden monocoque construction widely used in Germany. N.A.C.A. 4412 airfoil section. Wing span 52 ft. Wing area 214 sq.ft. Allowable load 400 lb. Sinking speed 2.5 ft./sec. Gliding ratio 23.5:1. Design tow speed 80 m.p.h. Placard speed 72 m.p.h. *Aero Digest*, October, 1940, pages 114, 128, 4 illus., 1 table.

Propellers

Curtiss Propeller Production. Machine shop, and the cuff, subassembly, inspection, and assembly departments are discussed, and some of the 55 operations employed in the manufacture of the hollow steel blades are described. Continued. *Aviation*, October, 1940, pages 42–43, 110, 112, 10 illus.

Rolling Airscrew Blanks. To overcome disadvantages in other methods of producing propeller blades, Eumuco, Ltd., have introduced a forging roll to replace the hammer previously used. Grain flow of the material is said to be improved, thereby increasing fatigue strength, and a considerable economy in metal is effected, in addition to a substantial increase of production rate. In the case of aluminum-alloy blades the dummy can be rolled directly from an extruded billet without machining the exterior to remove dross, but for magnesium-alloy blades, machining is still necessary. Essentially, the machine comprises two rolls arranged vertically, which make one complete revolution and then stop. Cut into the surface of each roll is a groove corresponding to half of the section of the dummy. Adjacent to the machine is arranged either a salt bath or an electric furnace for heating the billets prior to rolling. Description of the machine, arrangement of the rings and advantages obtained. *Aircraft Production*, September, 1940, pages 275–276, 4 illus.

Testing the Rotol Airscrews. The Rotol electric propeller, fitted to a Bristol Hercules engine, has successfully completed a test of 250 hr., during which period the propeller received no attention whatever. Period of 250 hr. is equivalent on a modern bomber to twice around the world. Brief reference only. *Flight*, September 26, 1940, page 202.

Rotol Electric Airscrew. Mechanical details, deicing, and maintenance of the Rotol electric propeller, and technique of operation to be used by the pilot in manipulating the controls on the instrument board are described in detail. Propeller can be flown as a constant-speed, a manually-controlled, or a fixed-pitch unit, and can be feathered quickly and easily in an emergency. For maneuvering of flying boats upon the water, its blades can be reversed to turn the aircraft within a circle of radius equal to the wing span. *Flight*, August 29, 1940, pages 168–169, 2 illus.

Correspondence. A. R. Weyl. Supplement to the historical facts mention in regard to tandem and coaxial counter-rotating propellers, as given

by Lt. H. M. McCoy in his article in the June issue of the Journal. *Royal Aeronautical Society, Jour.*, August, 1940, pages 677–678.

Equipment

New Equipment. Clicker Type LKD 2410 lightweight switch designed for use in aircraft. Mercury Super-Huskie tractor for towing heavy loads at airports. Dycer quick-detachable control couplings for aircraft. Wait photoelectric Speed Course used in measuring aircraft speeds. Abrams C-3 Explorer aerial topographic camera. Belden friction-type battery connector. Electronic Laboratories' Black Light or ultraviolet-ray instrument panel illumination developed in conjunction with the U.S. Army Air Corps engineers. Adjusting tool for BG spark-plug electrodes. C-O-Two fire-fighting two- and four-wheeled hose-reel trailer units which can be attached to any truck or tractor. Mechanical Products Hummer self-contained mechanical starter for use in light aircraft. Goodrich flexible synthetic rubber nozzle for gasoline hose. Long or short descriptions of this equipment. *Aero Digest*, October, 1940, pages 182, 185–186, 189–190, 193, 4 illus.

Buyer's Log Book. Brief references to new materials, accessories, supplies and equipment of interest to the aviation industry. *Aviation*, August and October, 1940, pages 80–81 and 64–65, 18 illus.

Aircraft Instruments and Navigation

NAVIGATION

Navigation in a Nutshell. The map question in air navigation is considered, and a device for handling maps is described. East to west strips of the map are cut and rejoined end to end. Marked track line is a transparent graduated rule outside the case, held on the winder by steel clips pivoted radially on the edge, and prevented from slipping by friction buttons on its under side. Rule has a rotatable protraction on it marked with parallel gridlines on North. Overlap on the map must be allowed and whole thing requires two sets of half-million sheets for cutting up. Method of transition from one strip to the next during flight, and a system of roller and spreaders for winding up the map are described. *Aeroplane*, September 20, 1940, pages 328–329, 5 illus.

Armament

Effect of Windage on Projectiles with Special Reference to Aeroplane Gunnery. F. W. Lanchester. The elongate projectile discharged with a degree of spin imparted to it by the rifling of the piece is dealt with. The particular case of firing at right angles, or substantially right angles, to the direction of flight is alone considered but the method may be applied more generally. In the future the author believes the practice of firing at short range will gradually undergo change, and it will be found advantageous under certain conditions to open fire at much greater ranges than those which at present find favor. If an enemy aircraft can be picked out in silhouette against a luminous sky by a well-camouflaged airplane from beneath, and the range then determined, flying at the same speed on a parallel course, fire might well be opened at 500 yards range or more, using the sighting allowances given in the table (of ranges in feet and yards, windages, and windage allowances), or similarly computed allowances founded on more modern data, given for different airspeeds. The enemy would have scant chance of effecting a hit, being hampered by uncertainty as to range and bad visibility of his target.

Drift as distinct from windage, causes of gyroscopic drift and evidence, windage and broadside firing are discussed. *Flight*, September 5 1940, pages 186f–186h, 7 illus., 1 table.

"Oil Bombs" and Others. "Oil bomb" is not a bomb because it has a hard steel, not aluminum-alloy, case and has all the appearances of a piece of machinery. A dent about 12 in. has been made by this bomb in grazing land, and for a radius of 10 yd. the grass was saturated with oil. Theory is that bombs are filled with a mixture of gasoline and oil which helps to feed the flames once the fire has started. In one case the oil showed no inclination to burn at all and in another was easily extinguished. In any event its failure as an incendiary was palpable.

"The casing is about 3 ft. long with a longish cone at one end. The shape of the other end had been altered drastically by the impact with the ground, but seemed to be a wider cone. Between the two was a steel mill-edged collar, with a thread inside, suggesting that it had worked itself loose from the aeroplane. Are these secret weapons spinners or parts of the engine sump? Another mystery which is less mystifying is the use of carbide of calcium in incendiary bombs in place of the much publicized thermite. Many of the carbide incendiaries have failed to 'go off' or have fizzled out harmlessly. Little wonder, for unless some helpful A.F.S. man provides a supply with his hose there is not sufficient water to generate the acetylene gas. . . does it indicate that Germany is short of magnesium with which to make thermite incendiaries?" Short note. *Aeroplane*, September 20, 1940, page 310.

Elementary Mechanics of Bombing. Explanation of where the bomb drops and how it falls. Effect of air resistance, and the terminal velocity of the bomb are explained. Characteristics of dive bombing as differing from level bombing are pointed out. Chart gives data on the tracks of projectiles without air resistance. *Flight*, October 3, 1940, pages 269–270, 1 illus.

Parachutes

The Life Preservers. The Irvin Harnesuit is described and illustrated, and details of the Irvin Air Chutes are given. Parachute harness is clipped inside the suit itself and provision is made for quick attachment of the seat- or chest-type pack. A "Mae West" life belt is built in as well so that the Harnesuit serves the triple purpose of a warm garment, and an air and water life belt. *Aeroplane*, September 13, 1940, pages 298–299, 9 illus.

Electrical Equipment

Aircraft Electricity as the Airline Operator Sees It. P. C. Sandretto, United Airlines Transport Corp. Electrical system proposed is for the plane which will supersede the DC-4 and which will be a four-engine 100-passenger airplane with a gross weight of 100,000 lb. Power demand will be about 30 kw. Transformers can easily be designed to operate over the range of 300 to 900 cycles and to supply any voltage desired. Engines can be started on the ground from the battery which could supply the minimum essential loads in the event of failure of all four alternators. The a.c. switches can be made small to handle large power load without arcbacks. Direct current is available for variable-speed and high-torque motors as well as solenoids. Total weight of power supply system would be about 450 lb. or 15 lb./kw. It is suggested that four alternators each delivering 7.5 kw. of power at 115 volts be mounted directly on the four engines, being driven at about 4000 r.p.m., and delivering power at a frequency ranging from 300 to 900 cycles. Saving in wiring and conduit weight should be possible over a 24 volt system of about 350 lb. Transformer weights will be about 70 per cent of those for 60 cycle transformers, and weight for auxiliary power supplies should not be more than one half of that for rotating machinery.

Various apparatus which consume electricity for operational purposes on the DC-3 airplane are listed in one table, together with estimated amount of power they would consume on a typical 5 hr. flight. Tables also show: the electrical loads which a DC-3 uses to provide means for successfully avigating between two points; apparatus installed on board for convenience of passengers; and data showing that a 24 volt system would only be 5 lb. heavier than a system employing optimum voltage when the plane is a single-seater and 70 lb. heavier than the optimum system when the plane is a large twin-engine type. The DC-3 electrical system, and what the DC-4 electrical system is to be are described in detail, and a.c. power systems for aircraft are discussed. *S.A.E. Preprint for Nail. Aircraft Production Meeting*, October 31, 1940, 12 pages, 3 illus., 4 tables.

Testing Cables at Low Temperatures. Refrigeration plant of Coldair, Ltd., which is suitable for use in testing insulated cables for airplanes is very briefly described. British Air Ministry specifications require tests of the effect of cooling on the flexibility of cables with and without the outside braiding and lacquer. Future specifications for aircraft cables may incorporate fatigue tests on metallic conductors when subjected to low temperatures as well as tests of the effect of vibration on cables when installed in conduits. Short note. *Aeroplane*, September 27, 1940, page 359.

Miscellaneous Equipment

A New Floating Flare. New type of flare for Australian flying-boat operations at night is a streamlined container of brass extending into a large fin which keeps the flare pointed into the wind and prevents side gusts from blowing back around the flame shield. Container rotates freely and has a self-locking clip. Flame shield has a small inlet providing a forced draught on to the wick. Oil reservoir holds enough fuel for light for 4 hr. Special precautions are taken to disperse heat quickly. Flare is mounted on a kapok buoy and supported about 30 in. above the waterline. Brief reference only. *Aeroplane*, September 20, 1940, page 327.

Materials

Automotive Materials. Electromatic oil-tempered spring wire produced by Jones and Laughlin by an electric direct-resistance method. Molded Monsanto polystyrene used in the instrument panel of the Aeronca Super Chief airplane. Method of depositing a thin adherent coating of copper on steel backings for bearings before tinning to improve the bond, and consisting of etching the shells anodically before plating them (abstract from July issue of the International Tin Research and Development Council's periodical "Tin and Its Uses"). New material for cylinder-head and other gaskets developed in Germany to take the place of asbestos-base gaskets, and made up of three sheets or layers of synthetic rubber and two layers of steel-wire netting placed at 45° angles. Short descriptions. *Automotive Industries*, September 15, 1940, pages 264–266, 2 illus., 1 table.

Metals

NONFERROUS ALLOYS

Chill Cast Aluminum Alloy Rod—Its Use in Place of Extruded Rod. Restrictions placed on the use of jobnested aluminum for commercial purposes in the United Kingdom necessitate the use of an alternative material in the form of chill-cast aluminum-alloy rod. Properties of this material and its production in the plant of John Dale Metal Containers, Ltd., are briefly described. Table compares the properties of sand-cast and chill-cast rods of DTD.304, DTD.250, L.35, DTD.165 and L.8 alloys, and a photomicrograph of chill-cast rod in alloy DTD.304 is shown. *Metal Industry*, September 20, 1940, page 228, 1 illus., 1 table.

Diecasting Aluminum Alloys. Intensive development has enabled gravity diecasting to be adapted to a high-strength aluminum alloy having a proof stress (0.1 per cent) of more than 20 tons/sq.in. allied to a guaranteed elongation figure. Brief note on NA.226 which has already found many applications in diecast form, such as in making airplane control levers, and landing-wheel brackets. *Aeroplane*, September 20, 1940, page 330.

Practical Aspects of Hot Forging of Aluminum and Magnesium. Certain current fallacies regarding the forging of aluminum-base alloys are pointed out. Results of investigations of the behavior of different aluminum-base alloys when subjected to the forging operation (given by Zeerleder in "Zeit. fuer Metallkunde," 1937/29/305) are discussed in some detail with curves showing relative forgeability and specific upsetting pressures for these aluminum alloys. Curves for results of upsetting tests on Elektron AZM (given by Altwicker) are presented and discussed. Hot forging and pressing of light metals (given by Preusz in "TZ. fuer praktishe Metallbearbeitung") are discussed in great detail with tables of blank weights for workpiece, and operation schedule and times for forging, as well as illustrations of working plans, including: forging an eccentric cam ring; schedule for forging operations; comparison of steel and aluminum forging; forging the ultralight alloys; forging a magnesium-alloy fork lever; and use of hand dies. *Light Metals*, September, 1940, pages 215–222, 13 illus., 8 tables.

Tools for Machining Aluminum Alloys. W. A. Dean. Survey of modern American practice, including: tool designs for turning, milling and planing; recommended cuts, feeds and speeds for these operations; and data on sawing, grinding, polishing and buffing. From "Metal Progress." *Metal Industry*, August 16, 1940, pages 128–132, 3 illus., 3 tables.

TESTING OF METALS

New Constant to Replace Proof Stress. Certain disadvantages inherent to proof stress as the expression of a mechanical characteristic of a material are discussed, and an alternative of a less arbitrary nature and of wider applicability is proposed. H. Esser and H. Arend recently suggested (in "Archiv fuer Eisenhuettenwesen," 1940/10/425) that the stress-strain diagram be plotted on logarithmic coordinates. Test points for total elongation then range themselves along a line exhibiting a definite bend, stress at this point being called the bend-point stress, and the corresponding permanent set is known as the bend-point elongation. From results of test on a number of materials it was found that bend-point stress always lies below that for the 0.2 per cent proof stress, and, in many instances, below that for the 0.1 per cent proof stress.

Results of tests are shown in stress-strain diagrams for proof stress and in stress-strain diagrams plotted on logarithmic coordinates which apply to unalloyed aluminum, aluminum alloy containing 4.76 per cent Cu, 0.79 per cent Si and 0.12 per cent Mg, unalloyed aluminum 99.85 per cent pure, leaded brass, and electrolytic copper. Table gives physical properties of these metals and alloys determined by means of the diagrams. *Light Metals*, September, 1940, pages 225–226, 8 illus.

Tests for the Deep Drawing Qualities of Sheet Metal. H. W. Swift. Effect of lubrication on drawing, and conclusions. To ensure accuracy in

dimensions and absence of burrs in drawing tests, test blank should be machined on its outer edge. To minimize effects of drawing speed and parasitic friction, graphite lubrication should be used. Although positive blankholder clearances gave complete satisfaction in the exploratory work carried out, they are not readily adaptable to different thicknesses of blank and for commercial testing, some system of pressure blank holder would probably be more convenient. Sufficient radial clearance should be provided between punch and die to prevent ironing except during the final stage of pressing.

Apparatus designed by the author to combine the cupping and drawing tests is illustrated in a drawing. Data are given in tables in regard to lubrication of mild steel blanks, of brass sheet (64/36), and of aluminum sheet (normal-rolled soft), and summary comparison of lubricants. Continued. Extended abstract of Institution of Automobile Engineers paper. *Heat Treating & Forging*, August, 1940, pages 392–396, 2 illus., 4 tables.

WELDING AND CUTTING

Aluminum Soldering—Review of the Literature to July 1, 1939. W. Spraragen and G. E. Claussen. Flux and friction solders; friction soldering; flux soldering; wiping solder; reaction solder; special methods to secure improved adherence; corrosion of soldered aluminum joints; mechanical properties; metallurgical aspects; soldering aluminum alloys; soldering aluminum to other metals; and problems suggested for research. *Welding Jour., Weld. Res. Sup.*, September, 1940, pages 313s–322s, 2 tables.

Paint

Protection of Aircraft Plywood. R. B. Anderson. Protective-coating problems which had to be solved for the all-plywood wing of the Fairchild PT-19 trainer for the U.S. Army Air Corps are considered. Some of the tests conducted on plywood finishes are described. Results obtained in regard to moisture resistance, durability, plywood fuel tanks and putty to fill nail holes, dents and cracks are discussed. Tables show results of panel tests of the best four sealers, and of various finishing systems, especially of ivory color after a year's exposure in Florida. *Aero Digest*, October, 1940, pages 137–138, 1 illus., 2 tables.

Synthetic Resin Emulsions. H. C. Cheetham. Besides the very obvious advantage of being dilutable with water, emulsion paints with their synthetic-resin binder possess certain advantages in applications characteristic of emulsions. Chief of these is coverage on porous surfaces, where it is desired to avoid excessive penetration and consequent waste of paint. For this reason, emulsion paints are peculiarly suited to give economical water-resistant coatings on concrete, stucco, plaster, brick and masonry of all kinds, as well as on fiber board, composition board, and asphalt. As they are aqueous emulsions, it is possible to apply them to damp surfaces and obtain excellent adherence and sealing. *Modern Plastics*, September, 1940, pages 63, 94, 3 illus.

Plastics

Effect of Heat on Phenolic Laminates. S. W. Place. Behavior of phenolic laminates in applications or under conditions where they are subjected to elevated temperatures is covered in the investigation described. Data are given in the following tables: weight, dimension and hardness changes of phenolic laminates at 250°F., and also when heated at 360°F. for 24 hr.; tensile strength, hardness and water absorption of phenolic laminates after exposure at elevated temperatures, and also after exposure at 225° to 250°F. for 10 months; and standard specifications of the National Electrical Manufacturers Association for phenolic laminated products based on A.S.T.M. test methods. *Modern Plastics*, September, 1940, pages 59–62, 3 illus., 5 tables.

History of Plastics and Their Uses. G. M. Kline. Methods of compression molding, injection molding, transfer molding, extrusion molding and direct hydraulic molding are described. Commercial development of plastics in the United States from 1870 to 1939 is shown in a table. Concluded. *Modern Plastics*, September, 1940, pages 64–67, 90, 92, 94, 10 illus., 1 table.

Permanence of the Physical Properties of Plastics. J. Delmonte. Creep and cold-flow characteristics of solid plastic materials, as they are commercially available in sheet form, are analyzed. A general equation is developed which expresses plastic-deformation rate as a function of a coefficient of viscous resistance and of a coefficient of internal resistance. Data for laminated phenolics, polyvinyl chloride acetate, methyl methacrylate, polystyrene and cellulose acetate are compared. Experimental evidence is presented to show that, after a sufficient length of time, plastic deformation assumes a constant rate, continuing indefinitely.

Dual nature of the molecular structure of plastics is emphasized, in that true elastic deformation may occur, as well as a time-dependent plastic deformation, even at very low stresses. Further data are presented on the shrinkage of various plastics after exposure to elevated temperatures, and the swelling of these materials after exposure to high humidity or water immersion. Loss in impact strength upon exposure to high temperatures is disclosed for laminated plastics. A method of making deformation tests is described. *A.S.M.E. Trans.*, August, 1940, pages 513–522 and (disc.) 523–524, 24 illus., 1 table, 9 equations.

Wood

Casein Glues. Two kinds of Casco cold-water casein glues, manufactured by Leicester, Lovell and Co., were recently subjected to exacting tests in the Forest Products Research Laboratory to determine whether there was any foundation to the belief in the aircraft industry that casein-glued joints are subject to attack by mold spores, and that they even encourage growths of this kind. There is no doubt that certain casein adhesives are susceptible to mold growth, and casein phosphate adhesive was also tested for comparison. Brief note. *Aircraft Production*, September, 1940, page 276, 1 illus.

Modern Wooden Construction. A. R. Weyl. Phenolic formaldehyde adhesives, urea formaldehyde (carbamide) resin adhesives, Klemm glue, Kaurit glue folio, and Kaurit cold glue powder, as well as special synthetic adhesives such as Yavan glue, cellulose adhesives and polyvinylester adhesives (P²folio) are discussed in detail from the viewpoint of their application in aircraft construction. Metal-wood bending adhesives are briefly considered. Continued. *Aircraft Engg.*, September, 1940, pages 284–285.

Fuels and Lubricants

Aero Fuels Today and Tomorrow. B. O. Lisle. In regard to fuels for high-altitude flying, and from the standpoint of freedom from vapor lock and evaporation losses, it will be necessary either to provide special cooling devices with the regular aviation gasoline or to use less volatile fuels, according to A. E. Robertson of the Standard Oil Development Company. In case the latter alternative is adopted, safety fuels are particularly advantageous. They will compete for the raw materials now being used for manufacture of high-test gasolines, but the demand for safety fuel, as it arises, may result in the development of processes basically new. They will have a lower octane number than blending agents of normal volatility produced from the same feed stock, but can be expected to lie between 85 and 100 octane and may go higher because of the good lead susceptibility. Inspection data on safety fuels and regular aviation gasoline are compared in a table. Problem of the production of low-volatility gasoline is discussed. Reference is made to triptan, developed by G. Egloff, which has a 125-octane rating and possesses twice the combustive power of 75-octane gasoline. *Flying and Popular Aviation*, October, 1940, pages 49–50, 76, 3 illus.

Production and Operation of Military Aircraft

Where Should Your New Plant Be Built? Local protection factors to be considered in the selection of a location for an industrial plant include the protection of the plant water and power supply, of the plant itself from direct bombardment, and of personnel and material transportation means to and from the plant. These factors are explained, and general location factors are discussed, including: distance from possible take-off points of enemy attackers; isolation from other plants, requiring dispersion of enemy air forces in attacking it; location of plant near other plants, enabling concentration of protecting forces; and location of the plant in a general industrial area, providing good labor market and flexibility of operations in emergency. *Aviation*, August, 1940, pages 55, 120, 122.

GERMANY

Production in Germany. Present annual output of the German Industry would be about 30,000 machines—2500 per month, on the basis of C. Rougeron's method of estimating production. "Yet even in Germany 25 workmen per machine per year is not considered sufficient. If we take 28.8 (the average between 25 and 32.6) as a more reasonable figure, we arrive at a total of 25,347 machines—about 2,110 per month. By Mr. Wright's method we get a monthly output of 2,000 units of the approximate average weight of 10,000 lb. each.....If again we accept the total losses as having been 5,000 machines since the war began, a high estimate, we find....Germany with a total of at least 16,000 operational aeroplanes and an absolute total of about 30,000 machines—a figure which agrees well enough with the statement in 'Aviation!'"

The fourteen types of fighters, bombers, troop carriers and seaplanes making up Germany's first line strength are listed, and their production discussed. The Me. 110 went into production early in 1939 and about 1000 are known to have been built now. The He. 113, Germany's newest fighter, was not in production until early in 1940. Messerschmitt output is estimated at 10 airplanes per day from 10 known factories, Heinkel at 15 per day at the very least, Junkers at 25 per day from at least 10 factories, Dornier 10 per day from not less than 10 plants; or from four great designing firms a minimum total output of 60 per day or 1800 per month, of types to go into operational squadrons. A check is made on these output figures by means of the number of men reported employed in aircraft factories in Germany. *Aeroplane*, August 2, 1940, pages 113–114, 2 illus.

Stukas by the Thousand. Junkers Ju. 87B Stuka dive bombers are said to be in mass production and many factories are reported to be concentrating on it. Two indications are given which may allow a comparatively accurate estimate to be made of how many will be available when the "attack for final victory comes." Of the Ju. 88 twin-engine dive bombers ordered it was said that 4000 had to be delivered by the beginning of September, 1940. Plants in which this type is being built are listed. It is estimated that 6000 Ju. 87s are under production. There is also evidence that a new Henschel two-engine dive bomber is now in production. Brief note. *Aeroplane*, July 26, 1940, page 92, 2 illus.

GREAT BRITAIN

Factory Versus Bomber. F. Chichester. "Before the War, Germany was said to have a lot of its vulnerable production underground already, and we were told of underground offices waiting fully equipped right down to the sharpened pencils on the desks. The sooner Britain makes herself bombproof and gets back again to earning a national income the sooner she can resume her role of a Great Power." Underground factories are recommended and weak spots in camouflage as an alternative to underground factories are pointed out. The only test of the value of camouflage is said to be the inspection of factory and camouflage from the air. *Aeroplane*, August 9, 1940, page 140.

U.S.A.

Procurement for Defense. Brig. Gen. G. Brett. Contribution of the aeronautical industry toward expansion, and salient contributory features of the Air Corps program are discussed, including: basic materials (aluminum, steel, copper, rubber and magnesium); essential services (labor, machine tools, transportation, and gasoline); miscellaneous equipment (parachutes, flying clothing and other textile products, optics, and paper); airplane evaluation procedure; procurement for present conditions; and experimental engineering and research. *Aviation*, August, 1940, pages 42–43, 122, 130, 134.

Standardization as Applied to Aircraft. J. T. Thompson, The Glenn L. Martin Co. "While Army-Navy Standard parts may be successfully used in all types of Service and commercial aircraft with complete satisfaction, it must be remembered that these standards are rather old and do not reflect the degree of modern design frequently desired to correspond with the construction of modern aircraft.....from the point of view of the manufacturer building aircraft for both Services, it has been difficult to understand the reason for the inability of the Army and Navy to reach an agreement for standardization in cases of many important items. Since the origination of the Permanent Working Committee of the Aeronautical Board, this situation appears to be improving; but there are still many delicate subjects to be attacked by this Committee."

Advantages of cooperative standardization of aircraft are dealt with, and the means by which it is now being accomplished are described including aims and purposes of the Company Standards, Western and Eastern Aircraft Standards Committees, and the S.A.E. Aircraft Standards Division. Means for improvement are pointed out. *S.A.E. Preprint for Natl. Aircraft Production Meeting*, October 31, 1940.

Speeding Aircraft Production. Donald W. Douglas. An analysis of the military market of the United States under the existing emergency, which is given, is considered of great importance because it illustrates the fact that aircraft production is a unique problem that is not to be solved by conventional mass-production methods. The necessity for keeping the aircraft plants flexible so that they can be tooled quickly for production on a new model and for the various factories to be geared to the research laboratories and engineering departments are pointed out.

Obstacles in the way of our expanded production program are considered.

Recommendations are made for the following: determination of a program to meet the need as visualized by our statesmen and military experts; the elimination of shortage of trained personnel; coordinated program for determining priority on orders for parts, supplies, materials, and accessories; and priority system for expediting machinery and equipment orders needed for aircraft-plant expansion. Basic factors on which the attainment of our maximum production effort depends are discussed, covering obtaining the largest possible orders on aircraft of a single type, and breaking down design into the maximum possible number of component parts and subcontracting to outside organizations. Suggestions are presented on organizing aircraft manufacturing for greater production, under the assumption of a modern and efficient plant layout, and relate to the engineering, production planning, and material departments. It is believed that much attention should be given to the material department. *Aviation*, August, 1940, pages 44–45, 125, 128, 9 illus.

Aviation Faces Biggest Production Problem. L. Peat. Necessity for "freezing" the designs of aircraft, engines and accessories to get the aircraft into production is pointed out, and problems facing the aircraft industry in getting on a mass production basis are discussed with references to early problems of the automobile industry. *Automotive Industry*, October 1, 1940, pages 321–338 (alternate pages) 342, 413, 20 illus.

Defense Program in Action. W. S. Knudsen. It was decided to superimpose the defense load on the regular business load of the country in order first to take up the slack and then to adjust it if necessary. Development of defense program is traced. *Automotive Industries*, October 1, 1940, pages 283, 184 (suppl.).

Factory Training in the East. C. Norcross. Training problems arising in the eastern concentration of aircraft factories in efforts to meet the National Defense Program are discussed, covering the Republic Aviation, Grumman Aircraft, Brewster, Wright Aeronautical, Pratt and Whitney, Glenn L. Martin, and Curtiss Aeroplane Division companies. *Aviation*, October, 1940, pages 34–35, 100, 126, 2 illus.

Intensified Output in U.S.A. "How much can America aid Britain?" The time factor in achieving a production of 3000 aircraft per month is discussed with references to statements by Lord Beaverbrook, W. S. Knudsen and T. P. Wright. Data are given on large American airplane factories and aircraft exports for 1939 and 1940. *Aircraft Production*, September, 1940, pages 294–295, 2 tables.

Mobilizing Sub-Contracting Facilities as Told to Aviation by Harvey L. Williams. Work of the Connecticut Aeronautical Commission since August, 1939, in coordinating productive facilities of Connecticut manufacturers with the growing needs of the aircraft industry. *Aviation*, August, 1940, pages 50–51, 116.

Air Associates' New Plant at Bendix, N. J. Layout, construction, and equipment are described in detail. *Aero Digest*, October, 1940, pages 116–117, 120, 125, 8 illus.

Expansion of Piper's Production Facilities. Present facilities and the new plant of the Piper Aircraft Corp. are described. *Aero Digest*, October, 1940, pages 86–88, 7 illus.

Meteorology

An Improved Electrical Hygrometer and Its Applications. F. W. Dunmore, National Bureau of Standards. Electric hygrometer described consists of an aluminum tube coated with polystyrene and wound with a bifilar winding of bare palladium wire. Unit is then coated with a thin film of polyvinyl acetate with an amount of lithium chloride in it depending upon the humidity range to be covered. Electrical resistance of the film between the two coils is a function of humidity. If appreciable temperature changes are involved a correction is applied. Advantages of the use of these materials are pointed out.

With several units of different sensitivity in parallel, with resistors in series with each, humidities from 10 to 100 per cent may be measured using a single scale of an indicating instrument. Electrical hygrometer units have been made which have not varied more than 2 to 3 per cent over a period of several months. Flight tests with two radiosondes carried by the same balloon, one using the electric hygrometer and the other the hair-type hygrometer, showed that marked changes in humidity were recorded by the electric hygrometer which the hair unit failed to register. Construction details, operating characteristics in d.c. radiosonde circuits and in a.c. measuring circuits, designs for special uses, and radio soundings using the instrument are described. *Am. Meteorological Soc., Bul.*, June, 1940, pages 249–256, 7 illus.

Fog: Its Causes and Forecasting with Special Reference to Eastern and Southern United States. J. J. George, Eastern Air Lines. Quantitative studies of fog causes and forecasting at certain airports (Atlanta, Ga., Chattanooga, Tenn., Camden, N.J., Richmond, Va., and Louisville, Ky.). Series of studies abstracted were designed to serve only one purpose: to enable fog or low-ceiling conditions which would affect airplane operations to be forecast for certain specific stations sufficiently in advance so that the operation could be intelligently directed. To be continued. *Am. Meteorological Soc., Bul.*, June, 1940, pages 261–269, 5 illus., 3 tables.

Engine Design and Research

Supercharged Aircraft Ignition Harness. C. E. Swanson, Northwest Airlines. Air free from harmful ingredients is supplied to the space within the spark plug shield chambers at a pressure considerably in excess of that of the surrounding atmosphere in the ignition distribution system described. Contaminated air may be removed from these regions either through inherent leaks of the harness, or, if insufficient, by the provision of other openings in the shielding. Air within the harness at a pressure above atmospheric will prevent entrance of water, deicer fluid, and oils into the harness during all flight conditions, including periods of rapid descent. Increasing the density of the air within suppresses the corona and chemical actions associated with it. With the interior of the harness dry, no moisture exists to combine with nitric dioxide to form nitrous and nitric acid. Entire fleet of Northwest Airlines' Douglas DC-3 is equipped with this type of harness and flight service exceeds 5,000,000 engine miles.

Problems in securing satisfactory transmission of electrical energy to the spark plugs of aircraft engines are discussed in detail, including: dead air spaces contaminated with injurious gases, acids, fluids, and oils and sources of contamination; wide variations of atmospheric pressures encountered in flight; prediction of voltages at which corona will make its appearance; and determination of the effect which various circuit dimensions and constants have upon the corona which is dependent on the density of the air within the spark plug shield chamber. Various methods and schemes employed to eliminate the troubles associated with ignition distribution are described and it is shown that all have some serious inherent faults or inadequacies. *S.A.E. Preprint for Natl. Aircraft Production Meeting*, October 31, 1940, 14 pages, 21 equations.

Fatigue Strength of Castings Improved by New Screw Thread System. H. Caminez, Air Associates, Inc. Not only may fatigue failures in screws or studs be prevented but fatigue strength of aluminum-alloy castings may be increased and occurrence of fatigue cracks may be avoided by use of the Aero-Thread system described. The Aero-Thread insert distributes the load over all the threads in engagement and thereby prevents high stress concentrations in the end threads. Should failure of the screw occur, neither the tapped hole, nor the insert is damaged. System tends to prevent fatigue cracks from starting in the light-alloy part, and the insert has the ability to conform to the deflection of the light-alloy thread surface.

Applications of the Aero-Thread system described and shown in drawings include: screw or stud and nut thread profile; alloy-steel cylinder holddown stud used in forged-aluminum aircraft-engine crankcase; steel cylinder-flange stud in a magnesium-alloy crankcase; steel capscrew in a high-strength aluminum-alloy casting; aluminum-alloy capscrew for holding a coverplate casting on an aircraft engine; aluminum-alloy capscrew for attaching a base-mounted aircraft magneto; high-strengtn capscrew in the cylinder flange of a steel crankcase; system for connecting-rod cap bolts in aircraft engine; nut on an engine crankshaft to hold a thrust bearing in place; high-strength steel stud in a high-pressure-steel-pipe flange forging; and standard $^{7}/_{8}$ in. diam. alloy-steel bolt and self-locking nut. *Aero Digest*, October, 1940, pages 102, 105–106, 109, 13 illus.

Altitude and the Aircraft Engine. E. F. Pierce. Paper presented at the Semi-Annual Meeting of the Society on June 10, and previously abstracted from preprint. *S.A.E. Jour. (Trans.)*, October, 1940, pages 421–431, 14 illus.

Boosting the Diesel. P. H. Sweitzer. By injection of liquid oxygen into the air intake, power output of a Diesel engine can be increased by as much as 55 per cent for a few minutes without detonation and without damaging strain in the engine, according to results of an investigation at Pennsylvania State College. With the use of oxygen to boost the power for take-off and to gain altitude, airplane engines one third smaller and lighter could be used. A 3000-hp. transport airplane would need about 160 lb. of oxygen to give an additional 1000 hp. If engines capable of 3000 hp. are throttled to 2000 hp. in cruising flight, then engines rated to develop the lower power could be used saving upward of 1500 lb. in weight, and boosted to 2700 hp. for take-off with a consumption of about 112 lb. of liquid oxygen. Brief abstract of A.S.M.E. paper. *Flight, Aircraft Engr. Sup.*, October 3, 1940, page 36.

Increasing the Strength of Keyways. Most common starting places of fatigue cracks in keyways are illustrated, and results obtained in recent German investigations are described. While the investigation did not find a complete solution to the problem, it was shown that the strength of the keyways could be improved by surface pressing which must be done by use of specially ground chisels. Short note. *Aircraft Production*, September, 1940, page 303, 1 illus.

Design of High Speed, Two-Stroke Engines. S. Treves. Theoretical results obtained in the preceding section are fully confirmed by experimental values arrived at in investigations carried out by various firms both in Europe and America. Experimental and practical data on the design of two-stroke engines are presented, including: port timing compared with that of the Dusenberg engine; problem of satisfactory idling characteristics; need for adequate supercharging pressure, even at low engine speed, in the case of the double-piston engine; automatic valve and inlet pipe designed to prevent backfiring; design of the cylinder; choice of type of piston, the need for very intensive cooling of the piston crown, and an arrangement for the oil cooling of pistons; piston rings that cannot rotate in their grooves; connecting rods and crankshaft; ignition; carburetor; design of a four-cylinder double-piston-type two-stroke engine with two symmetrically mounted blowers; strong influence of the exhaust pipe on the operation of any two-stroke engine, and the phenomenon resulting in loss of engine power; and importance of realizing and foreseeing the complicated phenomena characterizing scavenging and exhaust periods. Continued. *Automotive Industries*, September 15, 1940, pages 251–258, 16 illus.

The Problem of Valve-Stem and Valve-Head Deposits. A. T. Colwell. Remedies that have been used on aircraft engines, as well as automotive remedies are outlined, and an analysis made from two aircraft engines in a study of valve deposits is presented in a table. Worst build-up occurs with lean-mixture operation. Proper metering of oil to the valve stem, with good circulation of oil in the rocker box definitely reduces the deposit. Withdrawing the valve-head of the guide into the boss somewhat might be effective. Varnish on the stem near the tip end is a combination of temperature, type of oil and oil flow. Oils with good oxidation resistance at high temperatures have definitely been proved to cause the least trouble. Design problem is to attempt to get a valve-stem temperature at the top of the guide which will not cause oil decomposition; or to meter the oil so that the deposit formed is not thick enough to cause trouble between overhauls; or to remove the deposit in some way as it is formed. Aircraft-engine and automotive remedies for preventing valve deposits are presented. The dual-diameter stem with chrome plating, the turning valve, and high boss with good cooling were found particularly effective in test work carried on by Thompson Products. It is believed that insufficient research work has been done on this specific problem by those dealing with fuels and lubricants, and that it merits more study. *S.A.E. Jour. (Trans.)* September, 1940, pages 358–365, 24 illus., 1 table.

Engine Cowling and Cooling

Laminar-Flow Heat-Transfer Coefficients for Ducts. R. H. Norris and D. D. Streid, General Electric Co. Theoretically derived values of the heat-transfer coefficient for flat ducts with constant surface temperature are presented and compared with the corresponding results for round ducts which have been previously published. A few test data for air in flat ducts are compared with theoretical results. Results for both flat and round ducts are presented both in customary terms and in terms of the logarithmic-mean temperature difference, the latter providing a consistent basis for comparisons with heat-transfer data for turbulent flow. Some limiting values of the local heat-transfer coefficient for both constant surface temperature and constant heat input per unit length are tabulated, and some equations pertinent to very short ducts are included. *A.S.M.E. Trans.*, August, 1940, pages 525–532 and (disc.) 532–533, 5 illus., 2 tables, 28 equations.

Engine Manufacture

Old Equipment No Bar to Carbides for Steel Cutting. J. R. Longwell. Considerations regarding power requirement, power transmission, centers, spindles, toolposts and holders, chip room and backlash are presented as an aid to checking the dependability of any piece of available machine-tool equipment to the use of cemented carbide tools for machining steel. *Aero Digest*, October, 1940, page 125, 1 illus.

Precision Machining. A. M. Swigert, Jr. Reasons for precision manufac-

ture, machining functions, precision machining methods, gages, machining cycles, superfinishing, advance in machine surfacing equipment and dimensional accuracy obtainable are discussed. *Automotive Industries*, October 1, 1940, pages 385, 386, 390, 393–397, 5 illus.

Engine Testing Equipment

New Research Building for Cummins. Engine-testing facilities are described. *Automotive Industries*, October 1, 1940, pages 316, 427, 1 illus.

Engines

The Diesel in the Air. Work is going forward on a Junkers 24 cylinder "square" Diesel to develop 2000 hp. at 3000 r.p.m. Diameter of four banks of cylinders which are set at 90° to each other, is 3 ft. 3 in. Frontal area is 8 sq.ft. and length 6 ft. 2 in. Weight is reputed to be only about 2000 lb. This engine may find service in the new big flying boats produced by Germany for the aerial blockage of Great Britain. The new Jumo 206 6-cylinder opposed-piston engine gives 1050 hp. for take-off and is fitted with a turbo-supercharger to maintain power to 20,000 ft. It weighs 1460 lb., or 1.39 lb./hp. and has a capacity of 1525 cu.in.

Germany has developed the compression-ignition heavy-oil aircraft engine to an extent that no other country has attempted, but as yet no German airplane powered with such an engine has flown over Britain. Three types of German Diesel-powered military aircraft which are in service in any numbers are the Junkers Ju.86K two-engine bomber, Dornier Do.18 reconnaissance flying boat, and Blohm and Voss Ha.139 four-engine float seaplane. All are powered with the 600 hp. Jumo 205C 6-cylinder horizontally-opposed-piston engine. Absence of the heavy-oil engine from any modern German bomber is thought to be due to the fact that the compression-ignition engine cannot be boosted to provide such high take-off power with heavy loads, and that the Diesel engine at present requires more maintenance and more frequent overhaul. Short note. *Aeroplane*, September 20, 1940, page 310.

Mercedes-Benz Model DB 601. P. H. Wilkinson. It would not be surprising to learn that at least 100,000 D.B. 601 engines have been produced during the years 1939 and 1940. Inverted cylinder construction and cantilever method of suspension in the airplane permit interchangeability between both models of the Mercedes-Benz engine and the Junkers Jumo 211, which is of almost identical size and power output. Supercharger is mounted in a similar manner to that of the Junkers Jumo 211 engine and is gear-driven from a transverse shaft at right angles to the axis of the crankshaft permitting full advantage to be taken of the high-velocity airstream emanating from the periphery of the closed-type high-speed impeller. Direct fuel injection into the cylinders is provided by a 12 unit high-pressure pump mounted between the cylinder blocks where it is fed by a Graetzin transfer pump. Latest model is rated at 1200 hp. for one minute for take-off and develops this power at an altitude of 16,400 ft., and 850 hp. at 25,000 ft. It operates on 87-octane gasoline. Engine has been used extensively to power large numbers of Heinkel He.111 bombers, Me.109 fighters, Do.1 and Do.-215 bombers, He.112 interceptors and Me.110 convoy-fighters or destroyers. Engine is a 12-cylinder water-cooled inverted 60-deg. vee geared-drive 4-cycle type. Bore and stroke 5.90 × 6.30 in. Displacement 2070 cu.in. Length 68 in. Area 6.2 sq.ft. Total weight (dry) 1265 lb. Specific weight 1.05 lb./hp. Fuel consumption 0.45 lb./hp.-hr. Oil consumption 0.018 lb./hp.-hr. Compression ratio 6.8:1. *Aviation*, October, 1940, pages 61, 94, 1 illus.

Rolls-Royce Merlin. P. H. Wilkinson. "Will present-day Rolls-Royce Merlins be sufficiently up-to-date when we get them for the high-performance warplanes required for our National Defense during the years 1942 to 1945?" As it is improbable that these engines would begin to come off the assembly lines in any quantities much before 1942, we would have to take the last 3000 of the 9000 engines. It is said that the Merlin is difficult to produce and that it might be advisable to check up on this point before a large outlay of funds is committed to its production. Considerable modifications to the engine are essential if it is to be adapted to American mass-production methods. Rear section and mounting of the accessories and controls appear unduly complicated and the number of hand operations required during assembly appears excessive. Standardization of threaded parts and drives and mounts for accessories will cause considerable delay if some of the engines have to be built to American standards and others to British standards. Merlin engine for which Packard has accepted a contract and is tooling up for in Detroit is described in some detail with specifications. *Aviation*, August, 1940, pages 67–68, 116, 2 illus., 1 table.

Guiberson Aircraft-Type Diesel Engine. Sectional and installation views of the Buda Guiberson radial Diesel engine are shown and engine is described. The Buda Company is now in production on engines of this design for lightweight Army tanks and other ground equipment, and it is understood that 90 per cent of the parts are interchangeable with the Guiberson aircraft engine. *Automotive Industries*, October 1, 1940, pages 411–412, 4 illus.

Description of the Guiberson T-1020, A-1020 and T-1400 Diesel engines now available for export. *Aeroplane*, September 27, 1940, page 354, 1 illus.

America Goes Wet Again. Comparative performance figures are given for the 1145 hp. Rolls-Royce Merlin X 12 cylinder vee liquid-cooled engine, to be built by the Packard company, and the Allison V-1710-C15 1090 hp. engine. The Allison engine is described. Noses of the Boulton-Paul Defiant two-seater fighter and the Curtiss P-40 single-seater fighter, powered with Merlin and Allison engines, respectively, are illustrated for comparison.

The new 1200 hp. Lycoming Model O-1230 12 cylinder horizontally-opposed engine, designed for wing installation on multiengine aircraft, is illustrated on another page and details are given. *Aeroplane*, August 9, 1940, pages 155–156, 5 illus.

Parts and Accessories

Ceco Carburetor. Chandler-Groves non-icing diaphragm type of carburetor. Long description with drawings, showing functioning during take-off and with the mixture level in "cruising lean" position. *Flight*, September 12, 1940, pages 203–204, 2 illus.

Piston Rings and Gudgeon Pins. J. A. Oates. Each of the Phormicast piston-rings described is individually cast to its free shape so that ends of the gap exert a high pressure on the cylinder walls. By this means a damping effect is obtained which raises the natural period of vibration above that of the engine. Investigation has proved that the piston ring is merely a spring with a natural period of vibration of its own, and has shown the inaccuracy of established theories of maintaining a uniform distribution of pressure around a piston ring, and of keeping this pressure as low as possible to reduce engine friction and cylinder wear.

Production methods employed by the British firm of Hepworth and Grandage in the manufacture of piston rings and gudgeon pins are described, including: method of molding and molding machines used; means of obtaining essential uniformity of strength, elasticity and wearing qualities for each cast of metal by strict furnace control; machine-shop operations; thorough inspection required; production system evolved for the manufacture of large quantities of gudgeon pins; special grooved pin for aero engines and processes involved in its manufacture; drawing office work; and stores system. *Aircraft Production*, September, 1940, pages 285–290, 21 illus.

Aircraft Tanks

Fire Protection of Petrol Tanks. A. R. Weyl. Under the section devoted to "crash fires and modern solutions," recommendations on the gasoline tank protected against bullet holes and crash fires are given including: selection of materials in regard to electric nonconductivity, structural behavior under impact of fluid pressure waves, and weight; gasoline-tight joining of the shell parts; proper joining of fittings to shell tanks; baffle plates of nonmetallic materials; outer protection; enclosure of structure in a wire net electrically connected with other metal aircraft parts or in a nonmetallic outer casing; essential points in mounting tanks; design and mounting so that overflowing gasoline can neither reach the protective cover nor be collected nor soaked in by neighboring parts of the tank; provision of ventilation of the space around a gasoline tank; interchangeability of protected gasoline tanks for replacement; and incorporation of the fuel tank directly in the structure of the airplane. A gasoline tank recently discovered in a captured Heinkel bomber seems to correspond fairly closely with the recommendations outlined. Table shows the average unit weights of gasoline tanks of various metal and nonmetallic materials.

History of the development of protection of gasoline carried by airplanes is traced, and the reaction of bullets upon gasoline tanks is explained in great detail. Principles of protected tanks are discussed. It is concluded that: entry hole made by a bullet is harmless and no ignition will be connected with entry; sealing of a leak made by a bullet entering the tank is easy; exit leak effected by a bullet which has passed through the tank is large and presents difficulties in sealing; pressure waves set up by the bullet within the gasoline are the cause of the exit leak and will help to produce ignition; if the bullet can be made to stop inside the tank, no ignition may be expected; if the bullet can be separated from the gasoline fluid while inside the tank, the exit leak will be small; if the bullet can be freed from any gasoline at the moment it is leaving the tank, no ignition should take place; incendiary bullets designed to disintegrate inside a gasoline tank are unlikely to cause ignition. Reference is made to an official tank protection of the U.S. Air Corps. *Royal Aeronautical Soc., Jour.*, August, 1940, pages 657–674, 14 illus., 1 table.

Self-Sealing Oil Tanks. Principle adopted in the Henderson oil tank is that of evolving a material which, in a state of compression, can be trusted to close holes without help from the chemical action of gasoline or oil on rubber. Hencorite in this system is the middle layer of a sandwich. The tank which contains the oil is of tinned copper. Outside of it is the layer of Hencorite and outside that again is another layer of tinned copper. All three layers are molded together to make a homogeneous wall about $^5/_{16}$ in. thick. An 0.303 bullet was fired at about 25 yd. at the tank in front of which was placed a deflector plate consisting of a lead-coated steel sheet. Bullet struck the deflector plate, turned and pierced the tank broadside. At the same time, various pieces of the lead-coated steel splintered and entered the tank like shrapnel making five indentations and holes. The exit hole made by the bullet was about 2 in. from the base. All entry and exit holes were completely sealed. *Aeroplane*, September 13, 1940, page 300, 1 illus.

Aircraft Radio

An Ultra-High Frequency Superheterodyne Receiver for Direction Finding. L. C. L. Yuan and C. E. Miller, California Institute of Technology. The u.h.f. superheterodyne receiver described is simple in operation, has high sensitivity and stability, and has been designed and constructed primarily for direction finding on 1.67 meter waves. Receiver comprises two units. Converter unit consists of a 956 radio-frequency amplifier, a 954 mixer, and a 955 oscillator. The 220-kc. intermediate-frequency amplifier uses resistance-coupled high-μ television-type tubes and has a constant gain of 110,000 over a 110 kc. band. This flat intermediate frequency response allows for any slight variation in the oscillator or signal frequency, due to temperature variations, or other causes, without affecting receiver output. A duplex-diode triode, 6R7, is used as the combined detector and vaccum-tube voltmeter. A high gain and a high signal-to-noise ratio make the receiver well suited for direction-finding observations by the null-point method. *Rev. Scientific Instruments*, September, 1940, pages 273–276, 4 illus.

Aero Radio Digest. Radio Receptor Series 427–428 UHF airport traffic-control transmitters. Harvey-Wells Type 50-TC 50-watt aeronautical ground station communications transmitter. RCA installations of two-way radio apparatus for the PiperCoupe airplane. Bendix Type TA-12A four-frequency aircraft transmitter of the master oscillator type. International Telephone selenium rectifiers for aircraft radio work. Descriptions of this radio equipment. *Aero Digest*, October, 1940, pages 198, 201, 5 illus.

Aviation Radio. D. Fink. First issue—Wunderlich radiotelephone transmitter. Four G. E. frequency-modulation transmitters purchased by the C.A.B. for use in remote-control and telephone channel auxiliaries in Alaska. RCA Models AVR-20 and AVR-7H aircraft receivers. Lear Avia Model AMR-1 receiver, and for direction finding the AMRL-1 receiver, the AMT-1 transmitter and AMT-12 transmitter, all battery-operated. Impedance-measuring units purchased by C.A.B. for periodic checking of radio-range beacon stations throughout the United States and Alaska. Western Electric 10-channel radiotelephone.

Second issue—Bendix MN-31 automatic radio compass designed for use with the MN-26 direction-finding receiver. Harvey-Wells 50-watt dial-tuned radiotelephone ground transmitter using a single 500-ohm control circuit between remote control and transmitter proper. Descriptions of this radio equipment. *Aviation*, August and October, 1940, pages 83–84 and 62, 6 illus.

C.A.B. Radio Program for 1941. H. W. Roberts. Expansion program of the Civil Aeronautics Board, 1940 achievements, and plans for 1941 airways expansion are discussed. Progress of the C.A.B. airways and airway navigation and communication aids for the period 1932 through 1941 is shown in a chart. *Aero Digest*, October, 1940, pages 71–72, 205, 3 illus.

The Laryngophone. In the use of a microphone held in front of the mouth, noises in the atmosphere are picked up also. To eliminate this trouble, the laryngophone has been developed which picks up its sounds by direct vibration when held in contact with the larynx. Either a crystal or carbon microphone may be used, the former giving better quality, while the latter has greatest sensitivity. This invention may have an application in the cockpits of aircraft where the noise level is relatively high and has another advantage in that it can be used when wearing a gas mask. Brief reference only. *Flight*, September 19, 1940, page 235.

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